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THE AUTOMATIC SYSTEM OF TELEPHONY.

(Stated meeting held Wednesday, January 20, 1909.)

BY
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As soon as Prof. Bell had demonstrated, by his exhibit at the Centennial Exposition at Philadelphia, Pa., in 1876, that it was possible for two persons to talk with each other over a completed electrical circuit, inventors began to devise methods for connecting one telephone with another. As it was manifestly impossible for individual lines to extend from one telephone to every other telephone, it became evident that the lines from each telephone must terminate centrally in a common group or number of groups in order that connections could be conveniently made either by some mechanical agent or by a manual operator. While the possibility of making these connections mechanically was almost immediately suggested, naturally the first method that appealed to inventors as affording the readiest solution of the problem was that of manual operation. Hence arose the manual switchboard supervised by operators who, in response to the request of the subscriber, selected the particular line wanted and

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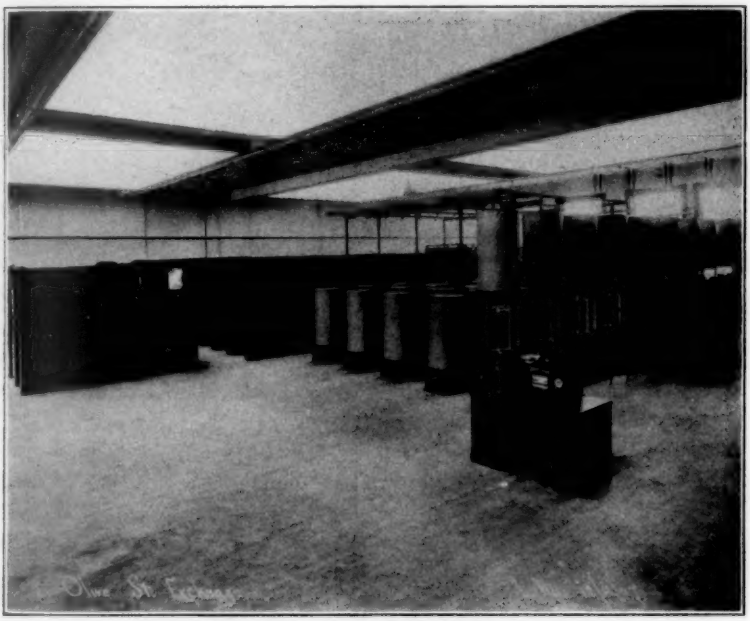
connected the line of the calling subscriber with it by hand. This method made telephony commercially possible and supplied a more or less satisfactory service. While manual switchboards were being rapidly developed, a few daring inventors persisted in the endeavor to develop a machine which would enable the telephone subscriber to make his own connections and disconnections. This has resulted in what to-day is known as the automatic switchboard.

The earliest known workers along this line were M. Daniel Connolly of Philadelphia, Pa., Thos. A. Connolly of Washington, D. C., and Thos. J. McTighe of Pittsburg, Pa. These gentlemen working in unison applied for their first patent on September 10, 1879, and the patent was issued in December of the same year, only three years after Prof. Bell's public demonstrations. The apparatus, however, did not prove a success commercially. Undaunted other inventors continued experiments along the same line with almost heroic fortitude. In spite of hardships, financial losses, and ridicule heaped upon them by the manufacturers of manual apparatus, efforts towards perfecting an automatic switchboard were persisted in for twenty-three years before substantial recognition was secured.

To-day there are several automatic switchboard systems on the market, but only one has attained commercial prominence.

Since the subject is a very large one, the discussion will be confined to this particular system, generally known as the Strowger. A. B. Strowger, after whom the system is named, was an undertaker in Kansas City, Mo. It is related that he was naturally very sensitive and retiring. In the conduct of his business it was frequently necessary for him to use the telephone, and he so often suffered from the mistakes, curt answers, interruptions, and delays of the operators that he determined to make a switchboard that needed no operators. He set to work, and the first tangible result was an application for a patent filed March 12, 1889. After many discouragements, Mr. Strowger, with the aid of his nephew, Mr. W. S. Strowger, and some mechanics, succeeded in 1890 in completing a working model. How crude this was may be surmised from the fact that it required five wires to operate the automatic switch from the telephone. Shortly after this the Strowgers were induced by Joseph Harris to move to Chicago, and in 1891 a company was incorporated, under the title Strowger Automatic Telephone Ex-

change, for the manufacture and promotion of the apparatus. Meanwhile changes and improvements were being made. The apparatus was exhibited in various cities over the country, in order to enlist capital and in order to secure a contract for a public exchange. These efforts were successful to an extent, and in 1892 the first public automatic telephone system was installed at La Porte, Ind., 13 years after Messrs. Connolly and McTighe applied for their patent. The fight was not yet won,



Interior Olive Street Exchange, San Francisco, Cal.

however, and for ten years longer the existence of the "Strowger Automatic Telephone Exchange" was a constant struggle. Time and again the prospect of bankruptcy stared its officers in the face. A few small plants were installed and leased on a royalty basis, however, and by various means enough money was secured to keep going. The officers never lost faith, and, above all, the apparatus was constantly improved, refined, and its possibilities developed.

The Strowgers dropped out of the company after a few years, but the work was carried on under the direction of A. E.

Keith, who joined the company in 1892. Finally the apparatus won a very substantial recognition, a new company was formed, with Joseph Harris as Vice-President and General Manager and A. E. Keith as Chief Engineer and General Superintendent, and in 1902 one of the largest telephone factories in the country was equipped by them for the exclusive manufacture of automatic switchboards. In the six years that have intervened since then, automatic telephone switchboards have been installed in many of our large cities, and have given great satisfaction, both to the companies operating them and to the telephone users. Equipment of this type is to-day operating successfully in such large cities as Chicago, Ill., Los Angeles, Cal., Portland, Ore., Oakland, Cal., Omaha, Neb., Grand Rapids, Mich., Sioux City, Ia., Columbus, Ohio, Dayton, Ohio, Wilmington, Del., and in many smaller cities.

In the city of Los Angeles alone equipment is installed for serving 20,000 subscribers automatically. Apparatus is now being installed in San Francisco, Cal., for a new automatic system, which will commence to give service with equipment for 15,000 lines. This number is expected to be but the nucleus of a much larger system.

While an automatic switchboard is a very complicated-looking piece of apparatus, its functions are not difficult to understand. Every telephone in each of our large cities is connected to the central office by a " line " which consists of a pair of wires. For the purpose of conversation between any two subscribers it is necessary that the terminals of their lines should be connected together for the time. When conversation is completed, the two lines should be promptly disconnected.

In order to operate the mechanisms of the automatic switchboard to make and break these connections, it is necessary to send electrical impulses over the lines which extend from each telephone to the central exchange. As with the manual telephone, these lines consist only of the two required to complete the metallic electrical circuit necessary for successful and satisfactory conversation.

If we wish to send electrical impulses to an electro-magnet over a considerable distance, and these impulses are variable in number as determined by the operator, the simplest form of completing the circuit would be by means of a push-button. For instance, in Fig. 1, if *A* is a contact connected with a lead

to ground at a telephone subscriber's station, *B* a push-button adapted to connecting the line *C* to the ground spring *A*, and if *D* is a coil at a central exchange connected to one side of a battery *E*, the other side of which is grounded, then on pressing the push-button a circuit is completed through the coil *D* over the line *C* and ground which takes the place of a second line. If the coil *D* can be energized in this way, it can be made to do work. This is perhaps the fundamental principle of automatic telephony in its simplest form. In order not to waste time and in order to avoid mistakes in counting on the part of the subscriber, the dial represented on the automatic wall telephone,

FIG. 1.

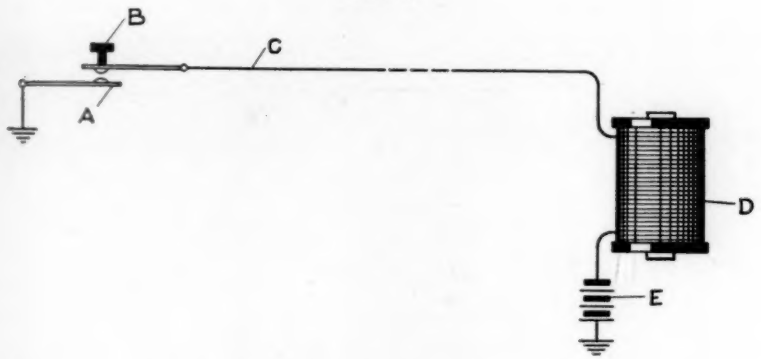


Fig. 2, was designed. The appearance of the telephone, it will be seen, differs but little from that of the manual, the only difference being the addition of this dial or calling device to the exterior of the box. This dial is connected by a shaft to an impulse wheel on the inside of the telephone. If the subscriber desires to send five impulses, for instance, he does not press a push-button five times, but instead inserts a finger in the dial opposite the figure five and pulls the dial around to a stop adjusted to retain the finger at a certain point. The impulse wheel, being secured to the dial, turns with it. The dial is then released and, actuated by a clock-spring, returns to its original position. In doing so the impulse wheel closes contact between one side of the line and ground five times. This design is merely to facilitate the sending of impulses to the automatic switchboard, and is more satisfactory than operating a push-button.

An automatic switchboard consists largely of machines

operated by the subscriber by means of this dial to make and break connections between his own line and any other at will. In order to understand how these machines accomplish their work, let us begin with a system of ten subscribers only.

Fig. 3 illustrates ten subscribers' lines, terminating in ten pairs of metal plates or "bank contacts," arranged in the arc of a circle and numbered from 1 to 10. A ratchet-wheel *R*, is arranged with it centre at the centre subtended by this arc of

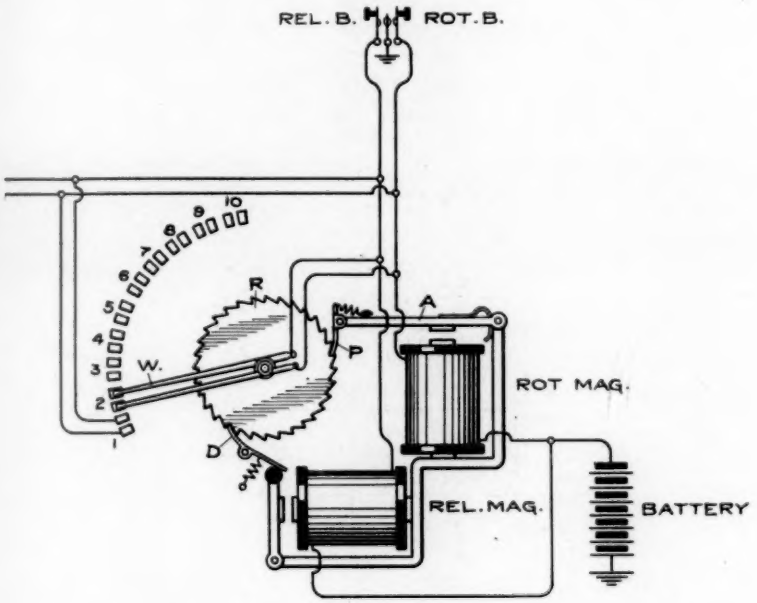
FIG. 2.

contacts, and carries a pair of springs *W* technically called a wiper. The line of subscriber No. 1, by whom it is supposed that this machine is used, is represented as being connected not only to the first pair of bank contacts but also to the wiper *W*, to the rotary magnets, and to the release and rotary push-buttons.

Now suppose that subscriber No. 1 wishes to connect to line No. 2. He presses twice the rotary push-button located at his telephone. This closes a circuit twice from battery through the rotary magnet. Each time that this circuit is completed, the rotary magnet is energized and attracts its armature, *A*. This armature carries at the end of its arm the pawl *P*, which engages the ratchet-wheel *R* and moves it, and with it the wiper *W*, one

step each time that the armature is attracted. Consequently, when *A* has been attracted and released two times, the wiper *W* will have been moved from its normal position at the left of the first pair of contacts and will rest upon pair No. 2 of bank contacts, thus bridging the gap between the terminals of line No. 1 and No. 2. By means not here shown subscriber No. 2 will be signalled and called to answer his telephone.

FIG. 3.

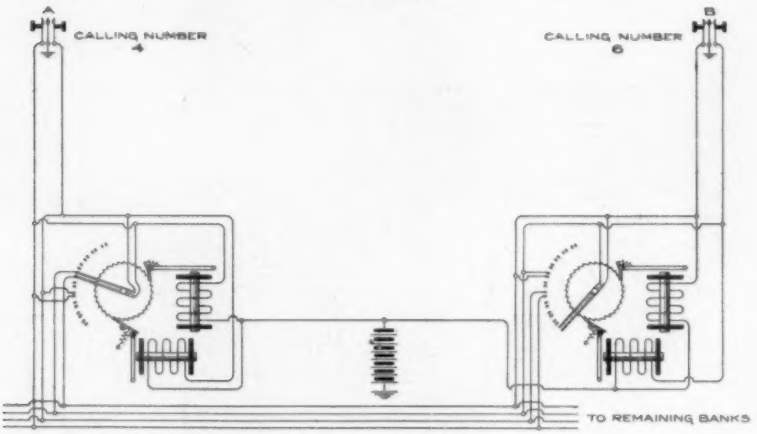


It is so arranged, that, when the conversation has been completed and the calling subscriber No. 1 hangs up his receiver, the release magnet will be momentarily energized and will attract its armature, thus pulling the retaining dog *D* out of engagement with the ratchet-wheel, which is then instantaneously returned to normal position by means of a clock-spring. This release is here represented as being effected by operating the push-button *Rel. B.* In a similar manner subscriber No. 1 could call any of the ten subscribers, or any of the other parties could by using his own machine call line No. 1.

Each of the subscribers of this system of ten would possess one of these switching mechanisms with its groups of ten bank

contacts. In order that each subscriber should be able to connect his line with that of every other line from his own bank, the corresponding contacts of the ten banks must be connected together. Any one of the ten subscribers, then, who desired to call subscriber number 6, for instance, would select the sixth contact of his own individual bank. This is illustrated in Fig. 4. Here subscriber A is represented as having called subscriber B. The lines from A are attached to the fourth pair of bank contacts of each bank, while the lines from B are in like manner attached to the sixth pair of contacts. Subscriber A with his

FIG. 4.

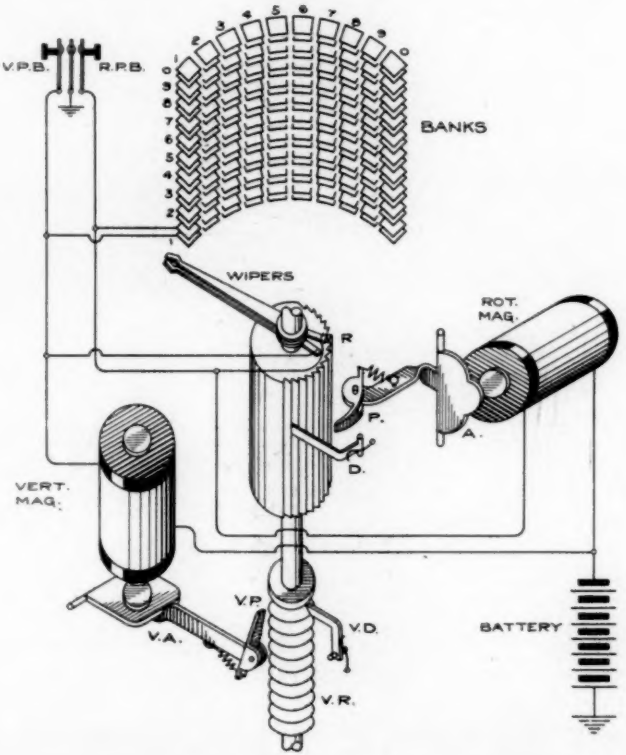


line wiper on the sixth contact of his bank in reality not only occupies the sixth contact of B's bank but also the sixth contact of the remaining banks in this system of ten. Since the lines of subscriber B alone are attached to the sixth contact, any other subscriber selecting that contact will signal B only.

Now consider a larger group of subscribers, a group of one hundred. The line terminals or bank contacts will now fill ten of these bank rows. These rows are superimposed one upon the other, somewhat as shown in Fig. 5. The number of the line connected to the first pair of contacts in the first, or lower row, would be 11; the number of the line connected to the second contact in this row would be 12; the next 13, etc. The number of the line connected to the first pair of contacts in the second row would be 21; the line connected to the second

pair of contacts in the second row would be 22, etc. It will be noted from this that in a system of one hundred lines every subscriber's number would contain two digits: the first digit would indicate in which horizontal row of bank contacts his line terminal could be found, and the second digit would indicate the exact pair of contacts in this row.

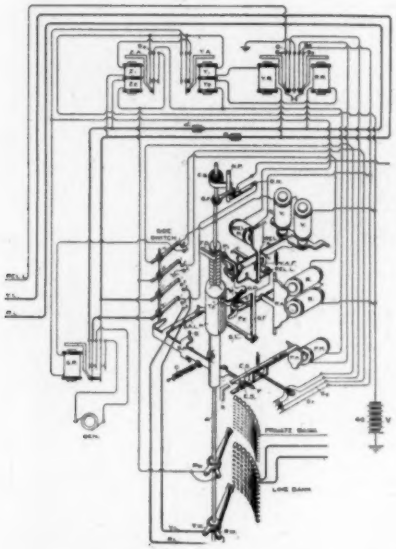
FIG. 5.



To get a rough idea of the method of obtaining a connection in a system of this size, we may again consider that each subscriber's line is connected to a pair of bank contacts and to a connecting machine, technically called a connector switch, somewhat after the fashion indicated in Fig. 5, which represents the connections for line No. 11. It will be noted that the important feature of this machine is the ratchet-wheel or hub *R*, which carries the wiper *W* previously represented in Fig. 3.

Fig. 5 also shows the rotary magnet with its armature *A* and pawl *P;* also the dog *D* for the retaining of the ratchet after each rotary step. The shaft on which the ratchet *R* is mounted is extended and carries another ratchet, *VR,* called the vertical ratchet. The vertical magnet is adapted to attract the vertical armature *VA,* which carries on its end the pawl *VP,* arranged to engage the vertical ratchet and to raise the shaft, and by means of it, the wiper one step whenever the magnet attracts

FIG. 6.



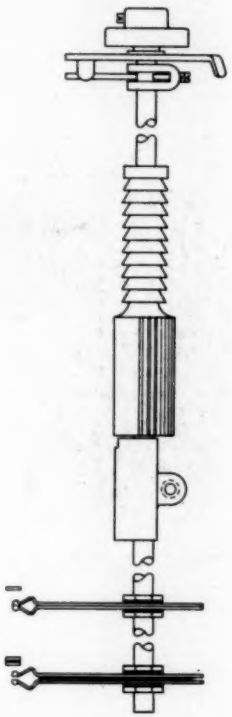
its armature. The vertical dog *VD* is adapted to drop into place each time the ratchet is raised one step, and thus retain the wiper in position.

It will be noted, that, by means of the vertical pawl and ratchet, the wiper may be raised to a point opposite any one of the ten horizontal rows of bank contact pairs. Then, by using the rotary pawl and ratchet, the shaft may be rotated until the wiper rests on any desired pair of bank contacts in that horizontal row. Thus, if the vertical magnet should be intermittently energized three times and the rotary magnet five times, the wiper would be raised to the third row of bank contacts and rotated five steps, in this manner connecting line 11 to line 35. The apparatus is so arranged that subscriber No. 11 may intermittently

energize the vertical and rotary magnets and control the movements of the wiper by turning the dial on his telephone, as has already been explained.

He is, therefore, equipped to operate his connector switch so as to place the wiper on the bank contacts of any one of the

FIG. 7.



one hundred lines terminating in the group. In addition to the mechanism here shown, means are provided for him to signal any subscriber with whom he connects and talk with him. Means are also provided so that, when he completes his conversation and restores his receiver to the switch-hook, the dogs *VD* and *D* will be withdrawn, and the shaft carrying the wiper and ratchets will be returned to normal position by the action of a clock-spring and gravity.

In reality the circuits and mechanism of the connector switch are more complex than those shown here, but this figure illustrates the general principle, which is the main object of this paper. Fig. 6 shows graphically the mechanical parts and actual circuits of a connector switch commonly used.

Fig. 7 shows a drawing of a shaft with rotary and vertical ratchets and with wipers attached; Fig. 8 is a photograph of an actual bank, or rather half a bank, containing fifty pairs of bank contacts,—that is, five rows of ten pairs each.

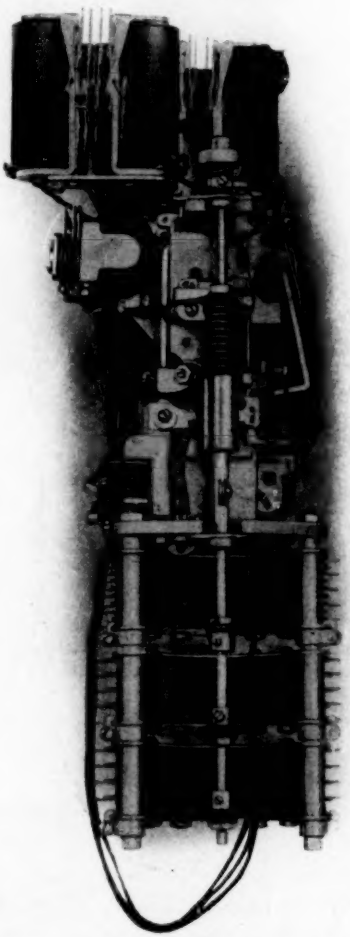
Fig. 9 shows a photograph of a complete connector switch with its shaft wipers, wiper cords, coils, relays, and banks. The

Fig. 8.

two lower banks are called the line banks. Each bank contains five rows of ten pairs of bank contacts. Two separate line banks with two sets of line wipers are employed, in order to give more space between the vertical bank rows. The lower line bank rows thus represent the odd levels from one to nine, the upper the even rows from two to ten. The top bank is what is technically called the private bank. This bank, together with the upper wiper called the private wiper, is used to establish a guard over a completed connection. That is, if the line wiper of a connector switch should rest on the terminals of line No. 48, for example, then the private wiper of this switch would rest on contact No. 48 in the private bank, and in this way would complete circuits which would establish a guarding potential on this contact wherever it appears in the banks of any other switches; consequently any other subscriber attempting to call

No. 48 while it is busy would automatically be given a busy signal. This "busy" signal consists of an intermittent buzzing sound transmitted to the subscriber's ear, and is the same as that often used in manual telephone systems.

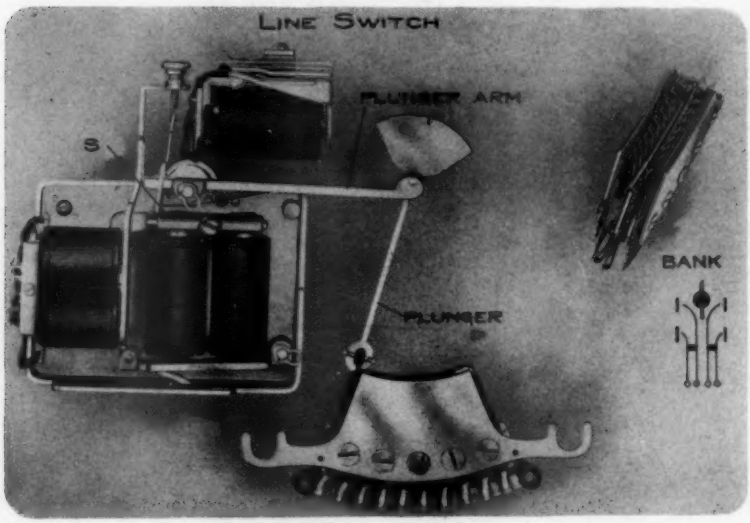
FIG. 9.



Although for the purpose of explanation I have supposed that there would be one connector switch connected to every subscriber's line, this is not the case in actual practice. The switchboard would be entirely too expensive to compete with manual switchboards if it were necessary to provide one hundred

of these connector switches for a group of one hundred subscribers. A switchboard is, therefore, so arranged that only enough connector switches are supplied to provide for every subscriber who might desire to use one at the busiest moment of the day. It has been found from experience that ten of these switches will generally be enough for the maximum demand of one hundred subscribers, even in a very busy central office. Having determined how many of these switches are actually needed, the next step is to provide some means for placing an

FIG. 10.



idle connector switch at the disposal of any subscriber who might wish to make a call. This is done by having each subscriber's line terminate in what is called a line switch. This is an inexpensive device, a photograph of which is shown in Fig. 10.

It will be noted that the essential feature of this switch is the plunger arm, which is pivoted near one of its ends, and which carries at its other end an arrow-like plunger. This plunger is pivoted so that its lower end may be swung back and forth over the bank. This bank consists of ten sets of bank springs; each set is made up of four movable springs and four contact plates, as shown in the lower right-hand corner of the illustration.

The line switch is so designed that when the trip magnets are energized it will release the plunger arm and allow it to plunge into a particular set of bank springs over which it may be poised at the instant. The effect of this is to press the bank springs against their contact plates and thereby close certain circuits which will be referred to more fully later. When con-

FIG. 11.

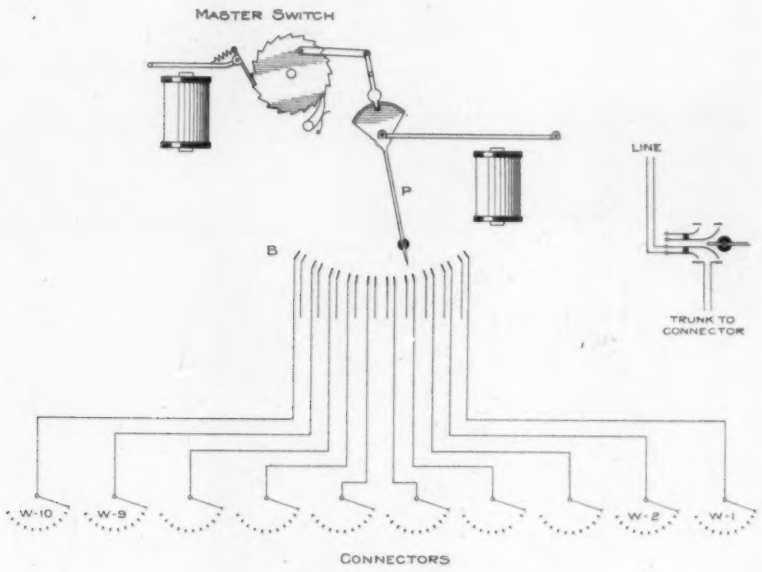
versation is completed, the plunger is automatically withdrawn from the bank and returned to normal position. Fig. 11 shows how these line switches are mounted in rows, so that the notch of the fan-shaped head of each plunger engages a knife-edge on what is called a master-switch shaft. This enables the mechanism controlling the master-switch shaft to control the plungers and to swing each plunger back and forth over its bank. These

plungers are not in constant motion, but are moved step by step as required. Ordinarily one hundred of the line switches are mounted together in a group, so that the plungers of the entire one hundred are controlled by one master switch.

It will be noted that all plungers which are in engagement with the shaft are in alignment, and that when the shaft swings them the whole one hundred will swing as one unit.

With this explanation of the line switch mechanism, the purpose of this apparatus can be readily understood by reference

FIG. 12.



to Fig. 12. In this figure *P* represents one hundred line switch plungers in alignment one behind the other, *B* represents the banks of these line switches which are also placed in alignment one behind the other. The first set of bank springs in each of these one hundred banks is connected, as illustrated, to a connector switch and its wiper *W*-1,—that is, the first set of bank springs in the entire one hundred is multipled together and the entire one hundred are connected to one connector switch. In a similar manner the second set of bank contacts in each of the one hundred banks is connected to another switch with its wiper *W*-2. The third set of bank contacts is multipled together and

connected to a third switch with its wiper *W*-3. In this way ten connector switches with their wipers, *W*-1 to *W*-10, are connected to the ten different line switch bank multiples. It will be noted that in the illustrations the plungers *P* are all poised over bank contacts No. 4. If now the plunger of switch No. 1 should be released, it would connect line No. 1 through to connector switch No. 4. It will be noted from the sketch in the other part of the figure that when the plungers are in the bank the two movable line springs are pressed against the two contact springs connected to the trunk leading to the connector switch. The instant that the plunger of switch No. 1 is thrust into the bank, the master-switch mechanism is energized and carries the remaining ninety-nine plungers one step forward so that they will be poised over bank contacts of trunk No. 5. This movement is carried out by a ratchet-wheel with its armature and pawl as indicated in the figure. The ninety-nine plungers now remain poised over trunk 5 until another subscriber calls. We will suppose that this is subscriber No. 2, and instantly the plunger of switch No. 2 is thrust into the bank contacts No. 5, and subscriber No. 2 is thus given access to connector switch No. 5. The master switch is immediately energized and carries the remaining plungers forward over trunk No. 6. In this way the master switch with its shaft always keeps the plungers of the idle lines poised over the bank contacts of trunks leading to idle connector switches. When the plungers have been swung as far as bank contacts No. 10, and this trunk has been occupied, they then start back again step by step to trunk No. 1. If on returning, trunk No. 9 is still busy, the master-switch automatically keeps the plungers in motion until a trunk leading to an idle connector switch is found. A subscriber's line switch is operated the moment that he pulls his dial, and before the dial starts to return he is already connected through to an idle connector switch, which is operated as already described to put him in connection with the particular subscriber he desires.

The real work of picking out the desired line is done by the connector switch, as described in the earlier part of this paper. The whole purpose of the line switch is to give the calling subscriber access to an idle connector. This makes it possible to reduce the number of connectors to the largest number ever needed at the busiest moment. One hundred subscribers are thus served by ten connector switches.

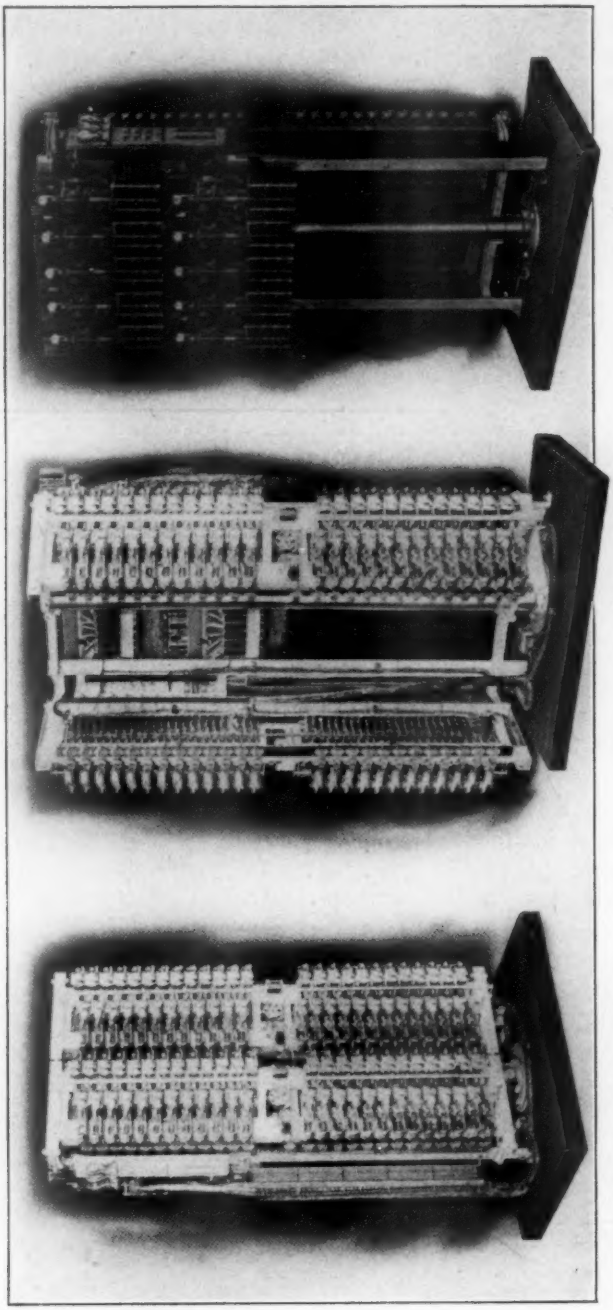


FIG. 13.

Fig. 13 shows three views of a complete board equipped with apparatus for one hundred subscribers. View *A* shows the one hundred line switches arranged in four groups of twenty-five each, the plungers of each group of twenty-five engaging with one section of the master-switch shaft.

There are two master switches shown mounted on the board, but only one is used at a time. The other is held in reserve so that in case of an accident it can immediately be thrown into engagement with the shaft and the disabled master switch be disconnected. View *B* shows that the line switches are mounted on two swinging shelves in such a way that the shelves may be turned outward on their hinges, giving free access to the cabling, bank wiring, etc., on the rear of the shelves. View *C* shows the other side of the switchboard, on which are carried connector switches mounted in two rows of five switches each.

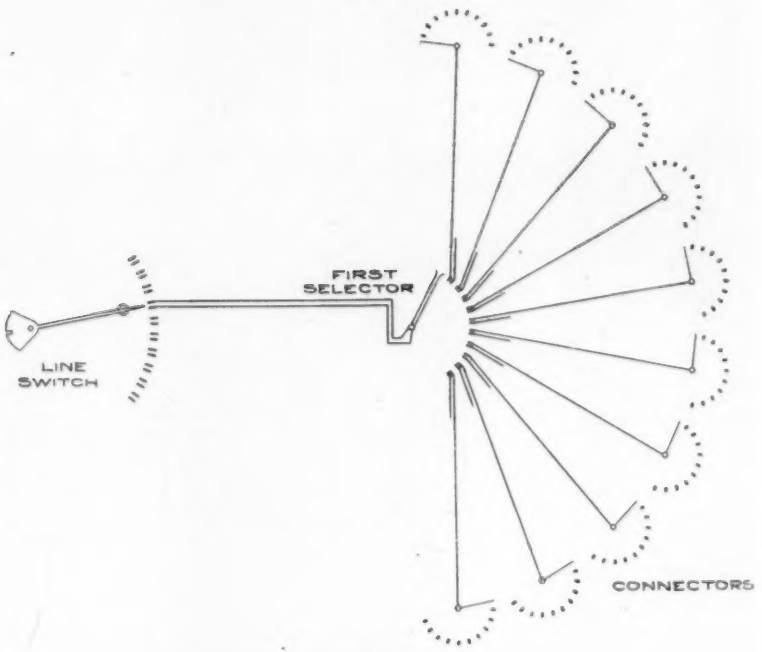
A system of more than one hundred subscribers—for example, a system of one thousand lines—is made by using ten of these one hundred line switchboards and installing apparatus for interconnecting between them. The machines which do this connecting are called selector switches. In general appearance they are very similar to the connector switches. The selector switches are interposed between the line switches and the connector switches, so that in a system of one thousand lines capacity a subscriber's line switch when it operates connects him through to an idle selector switch, instead of to an idle connector switch as previously described. The scheme is illustrated in Fig. 14.

To the left of this illustration is a line switch belonging to one of the ten one hundred groups of this one thousand line exchange. When the subscriber whose line is attached to this line switch pulls his dial, his line is immediately connected by the plunger to an idle trunk leading to one of ten selectors, exactly as in the previous case he was connected to one of ten connectors. As represented here bank contacts No. 4 are connected to a selector switch in the centre of the figure. The selector switch has a bank of one hundred pairs of contacts arranged in ten horizontal rows of ten pairs of contacts each. Each pair of contacts in the lower row—that is, row No. 1—is connected to one of the connector switches on one of the ten line switchboards used in the system, and which we will call the one hundred line group. Each pair of contacts in row No. 2 of the selector banks will be connected to a connector switch on another

one of the ten line switchboards, which will be designated as the two hundred line group. In like manner ten trunks from the ten pairs of contacts in row No. 3 of the selector banks will extend to ten connectors in the three hundred line group, and so on through the ten rows.

The operation of a selector switch is a little different from a connector, since its function is not to select a definite contact,

FIG. 14.

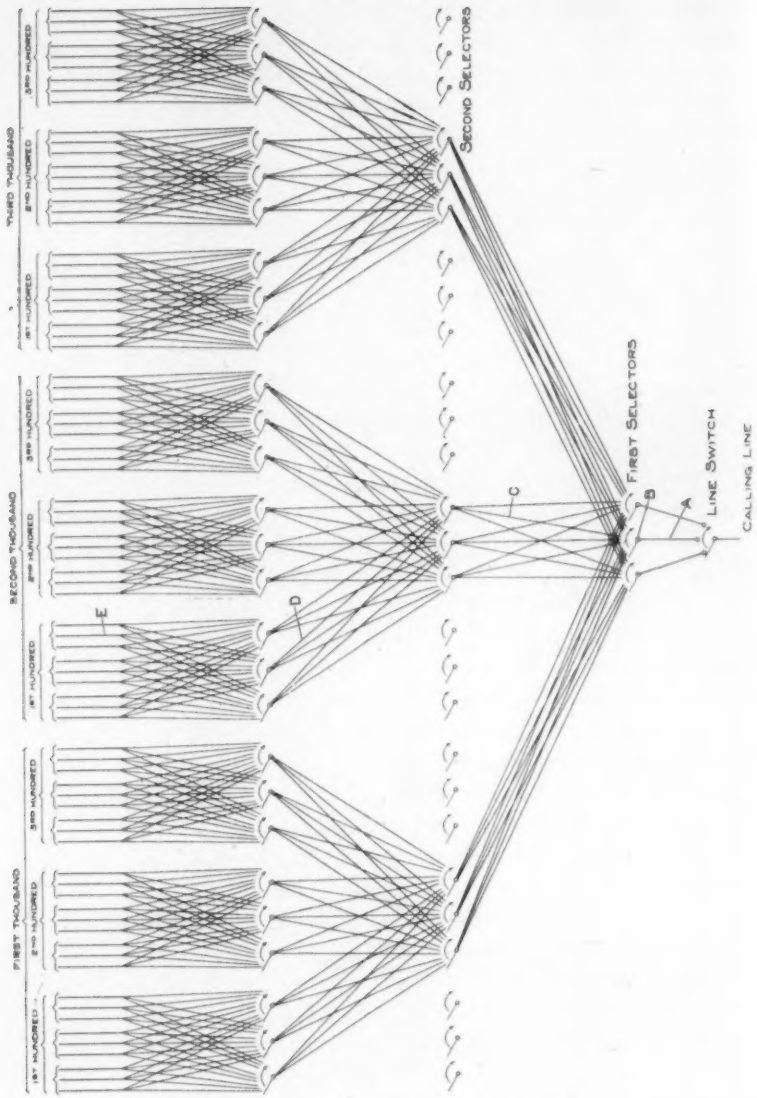


but only to select one trunk out of ten trunks any one of which will answer the purpose providing it is not occupied. That is, each level of a first selector bank represents a one hundred group in a one thousand exchange with ten pairs of trunks from each level to its particular one hundred group. Any one in that one hundred group can be reached over any one of the ten trunks, so that it is not necessary for the subscriber to pick out a particular trunk, but only one that is unoccupied. Since he cannot know which one is vacant, the selector switch is made to do this for him.

As in the case of the connector, a private bank is formed for the selector identical with that of the connector and for a similar purpose. When one subscriber then makes a call and obtains a certain trunk, a guarding potential is thrown upon that contact of this additional bank which corresponds to the particular line contact occupied. The selector in a simple manner is made to cut in automatically on the first contact of any particular level after the vertical impulses have been completed. The wipers of the selector of a second subscriber from the same group cutting in on the same level, instead of remaining upon the contact the multiple of which is already occupied, will rotate automatically to the second contact or until they engage a contact the corresponding private contact of which is not grounded by any other switch. Groups are therefore represented by one digit instead of two,—that is, by the digit which represents the proper level of the selector bank. To illustrate, a subscriber calling 752 would impart seven impulses to his group selector, which would then seize upon the first of the ten vacant trunks of the seventh level of his bank and connect his line with a connector in the 700 group. Five and two impulses respectively would then connect him with the No. 52 pair of contacts of the connector bank to which the lines of the called subscribers are attached.

A ten thousand system would consist of ten groups of one thousand, each one thousand group consisting of the ten groups of one hundred just described. The following diagram, Fig. 15, is an illustration of the trunking of an exchange having an ultimate capacity of ten thousand. A first selector in this case will be necessary to select thousand groups, the hundred groups of which will be selected by a second selector. One calling line is here represented attached to one line switch. This line switch has access to ten trunks, of which only three are here shown leading to three first selectors. Three levels of first selector banks with three trunks from each level lead to three second selectors in each of their respective thousand groups. In like manner three levels of the second selector banks with three trunks from each level lead to the connectors of their respective hundred groups in each thousand. From these connectors the line normals from each of these bank levels in each of the hundred groups extend to the various lines. As represented in this figure, each calling line has access to one line switch, ten first

FIG. 15.



selectors, one hundred second selectors, and one thousand connectors. To trace out a call explicitly we will assume that a subscriber desires number 2132. The line switch, we will assume, seizes the second trunk line *A*, connecting the calling line with

the second first selector *D* of the ten selectors belonging to the particular hundred group in which the calling subscriber is located. The first digit, 2, of the calling number indicates that the called subscriber belongs to the second thousand group. Consequently, the calling subscriber raises the wipers of his first selector to the second row or level of contacts of his bank, and seizes automatically, say, the third trunk line, *C*, assuming that the first two trunks are busy. His line now being connected to the third second selector, the subscriber causes the wiper of this selector to cut in on the first level of second selector bank contacts, since the digit 1 indicates that the subscriber wanted belongs to the first hundred group. Assuming that the first trunk is engaged, the wiper will stop on the second trunk, extending the calling line now to the second connector of the ten connectors in the first hundred group. Raising the connector wiper to the third level and rotating it to the second contact, connection is then completed with the called line *E*, the calling number of which is 2132.

This completes an elementary exposition of the principles of automatic telephony. The question may now arise, What is the excuse for the automatic exchange? What are its advantages? As with every question, there are always two sides, and the side adopted is generally the one most closely connected with one's business interests. Whether we want to be impartial or not, it is a very difficult matter to exercise an unbiassed judgment unless our interests lie far enough away to give us a good perspective. One of the reasons of Mr. Strowger for designing a system was to get rid of the telephone girl. Others have seemed to find the girl operator an attraction. However the case may be, there are very many substantial reasons for the existence of an automatic exchange which even the stanchest supporter of the manual systems cannot gainsay. There are two stand-points from which this subject may be viewed,—namely, that of the subscriber and that of the operating company,—but they are so interrelated that no attempt at distinctions will be made.

In automatic systems, instead of the manual switchboard operator is substituted a switchboard attendant who is able to take care of the necessary apparatus for one thousand subscribers and keep it up to its highest efficiency. In consequence the labor cost is much decreased, less expensive quarters are required, the cost of fuel and lighting is reduced, and the acces-

sories attendant upon the employment of operators are eliminated. The efficiency of an automatic exchange of small size is maintained at no greater expense than that of the manual, while in larger exchanges this item is much less than in a manual system of equal size. Increasing the capacity of the automatic exchange is a very simple matter and does not add to its complexity. The cost of operation per line increases slightly with the growth in the number of subscribers and in an arithmetical ratio. This increase in manual systems, on the contrary, is geometrical in nature and large enough to be a serious handicap.

The automatic telephone is a cosmopolite and speaks to every nationality in its own language. Connections are quick, disconnection instantaneous; consequently the same number of trunk lines in an automatic exchange represents a greater capacity for a certain number of calls within a fixed time limit than in a manual system. Regardless of the demand, the same facility in giving connections is maintained at all times. Confusion is impossible. A large number of subscribers may call simultaneously, at any hour of the day or night and each call will receive immediate attention and be taken care of with the same facility and dispatch that would be given were there only one call. When a line is busy, the subscriber is so informed at once, and he can repose the utmost confidence in the source of his information. Moreover, the service is secret. The frequent clicking, the lack of clearness on the line, the annoyance caused by knowing that a third person is intruding where three is a crowd is never known.

The automatic exchange probably never wears out. It may go through a process of renewal and aging, such as the human body experiences with a fixed time limit, but its comparative youth precludes this knowledge. The main part of the mechanisms deteriorates very slowly and such parts as are subject to wear and tear are easily replaced as needed, with the result that the exchange may be retained in its original efficiency for an indefinite period or until the march of progress requires its replacement by an improved equipment. Since, no matter what the size, the exchange is composed of groups of smaller exchanges connected by a certain percentage of trunk lines, these groups may be scattered over a large area. Thus by establishing these groups at the various local centres of a city or community, the first cost of an installation is greatly reduced and the expense of maintenance materially lessened. As

no operators are needed, these groups may often very profitably consist of only a single unit of one hundred subscribers and may be housed in any accessible quarters. In cases where ten per cent. of trunk lines is not sufficient to transact satisfactorily all business during the period of maximum calls, it is an easy matter to increase the number of trunks as desired. This may be done locally, wherever the activity is greatest, or may be carried throughout the exchange. These are some of the reasons for the automatic exchange which must appeal to all. There are others which must be left to individual choice, and still others which belong to the province of the engineers and students of the science.

PETROLEUM IN 1908.

The great gain in the production of petroleum in 1907 over 1906 required such a drain on all the great pools and developed so large a stock of unused crude oil that a further increase in 1908 was not logical, as a matter of either finance, trade requirements, or available petroleum resources. As the year went on, unprecedented floods in May and June and again in November brought disaster to the pipe lines of Oklahoma; and these storms also left a record of numerous oil tanks destroyed by lightning. In the Eastern fields the severe drouth also seriously interfered with well drilling. The decline in production in the Glenn pool and in various Texas and Louisiana pools increased the likelihood of a total smaller than in 1907.

Nevertheless, the actual record of the year shows a total beyond all records—between 175 and 180 million barrels, compared to 166 millions in 1907, or between 5 and 9 per cent. increase. The total value is proportionately greater still, for the price of the product in California increased and it remained steady in other fields, except the Gulf, where a comparatively groundless fear of overproduction from the new Markham and Goose Creek fields caused depression.

The increases came from the steady growth in Illinois and California. Neither field showed phenomenal development. California responded to the higher prices consistent with depleted stocks, and Illinois showed the continued effect of the great investments of the previous year in this new territory.

The year, however, had its sensations. They came in midsummer. On July 2 a large gusher was drilled in at Goose Creek, Harris County, Tex., and three days later a gusher of the spindletop type came in at Markham, in Matagorda County. This turned the attention of the oil producers in the Gulf field significantly farther south.

July 4 proved memorable in three widely separated regions. At Anse la Butte, La., a large gusher known as Lake No. 9 was drilled in. On the same day the Pearsons in Mexico opened a well that assumed the proportions of a volcano and made a new world's record for an outburst of oil and water. Incidentally it is interesting to note that on the same day the Oil City well at Tustanowicz produced the record spouter for Galicia.

The elasticity of the American oil trade is shown by the fact that stocks did not increase as much as would have been expected from the great product. The preparations of the year before led to better ability to transport the product to points of consumption.

SECTION OF PHOTOGRAPHY AND MICROSCOPY

(Stated meeting held Thursday, February 11, 1909.)

HIGH TIDES OF THE BAY OF FUNDY.

BY
J. W. RIDPATH,
Member of the Institute.

BEFORE considering these unusually high tides, perhaps it would be well to speak, in a brief way, of the principal causes of tides and why they are higher in some places than in others.

It is generally agreed that the earth is a globe, slightly flattened at the poles, the shorter or polar diameter being about 26 miles less than the longer or equatorial diameter. It if were possible to measure the extreme diameter of the earth together with its surrounding atmosphere, probably the difference between the polar and equatorial diameters would be found much greater; for the atmospheric tides no doubt greatly exceed the oceanic tides.

The shape of the earth, that of an oblate spheroid, flattened at the poles, is that which would naturally be assumed by a rapidly rotating liquid or plastic body. As a globe of fused material, the various substances of its composition would naturally arrange themselves very much in the order of their density; the more dense material at the centre. It has been found that the specific gravity of the earth as a whole slightly exceeds 5, say five-eighths that of iron, while that of the rocks on the surface ranges from 2.5 to 3, indicating that the interior of the earth is much more dense than its outer portions.

It may be that the earth is in the main a solid or rigid mass solidified by pressure, with only an envelope or superficial layer of less compressed or more plastic materials, composed largely of sand, clay, and water; the latter, owing to its greater mobility, readily flowing toward the equator—the part of greatest velocity in the rotary motion of the earth. As if in accordance with this

theory, which is disputed by some, we find that the majority of the important rivers flow toward the equator, one, the Mississippi, flowing up hill in order to reach its southern outlet; or to be more exact, the mouth of the Mississippi is farther from the centre of the earth than is its source.

Tides are the alternate rising and falling of the waters of the ocean at regular periods; that is, twice every twenty-five hours, nearly. Other things being equal, tides are higher at the equator and lower at the poles.

The principal cause of tides is the attraction of the sun and moon upon the waters of the ocean. But for this attractive influence, the waters of the ocean, having found their level, would cease to heave and swell, as they now do, and would remain undisturbed, save as the wind, by wave-action, might disturb the surface.

The distance of the moon from the earth is about thirty times the diameter of the earth, hence her tidal attraction is considerable. If a man could travel around the earth near the equator nine and one-half times, he would have travelled as far as to the moon. The sun, although much larger than the moon, is so far away that its tide-producing force is much less than that of our satellite; the relative effect being estimated as approximately one to three, in favor of the moon. The tidal impulse caused by the sun's attraction passes around the earth in twenty-four hours, while that of the moon requires nearly twenty-five hours to complete the circuit; therefore we have twice in each lunar month, tides that are higher than the mean.

The sun and moon act in the same direction when the moon is new and when it is full, causing high or spring tides, as they are called. When the moon is in her quarters the sun and moon act at right angles to each other, causing low or neap tides.

In obedience to gravity the waters nearest the moon rise and form tides. These waters are of course 4000 miles nearer the moon than is the centre of the earth; and as the water-particles move easily, owing to the mobility of water, they are drawn up, forming a protuberance above the mean form of the earth. The waters on the opposite side of the earth are as much farther away from the moon, hence they are equally less attracted, and form a similar protuberance. Thus, the waters in a straight line from the moon bulge from the earth's surface, as the particles of water are free to move, while the particles of land are

not. The waters nearest the moon move because they are drawn from the solid part of the earth, and the waters on the side farthest from the moon bulge because the solid earth is drawn from them; hence opposite sides of the earth always have similar tides whether high or low, at the same time. As a necessary consequence of the elevation of the water in the regions nearest to, and most remote from, the attracting body, there is a corresponding depression below the mean level of the sea at points ninety degrees therefrom.

The tide-producing influence travels at the rate of about 1000 miles per hour, therefore if there were no interfering land, and the ocean were deep enough,—about fifteen miles,—the tidal elevation might travel at the same rate. It has been found, in fact, that the tidal movement varies with the depth of water in the ocean, flowing much more slowly in shallow basins. The following table was published a few years ago to illustrate this phase of the subject:

10 feet deep	12.2 miles per hour
60 feet deep	30.0 miles per hour
100 feet deep	38.7 miles per hour
1000 feet deep	122.3 miles per hour
6000 feet deep	299.5 miles per hour

In a bay or indentation, decreasing in width from its entrance toward its head, the tide rises higher from the mouth upward, due principally to the fact that the vertical movement is partly changed into horizontal movement owing to the shoaling of the bottom. The highest points of these tide-waves usually fall behind the vertical of the attracting bodies because of the friction produced by the varying depths of water in the ocean, especially near shore lines.

At some places on the Atlantic coast the tide pours onto the shore with prodigious violence. On the rocky coast of Maine and the eastern coast of Nova Scotia the huge Atlantic waves and violent tidal movement beat with enormous force, but owing to the hardness and solidity of the rock but little harm is done, except to ships when they venture too near shore.

On the eastern coast of Nova Scotia the waters of the great tidal uplift are not confined between rocky barriers, hence they are free to spread northward to the gulf of St. Lawrence or southward opposite the United States coast. At Halifax, about midway along this eastern coast, the tide seldom rises above seven or

eight feet. But on the coast of Massachusetts, New Hampshire, and Maine, the tidal waters are somewhat confined by Cape Cod on the south and Nova Scotia on the northeast. Hence the incoming tidal waters are forced up the conical passage between New Brunswick and Nova Scotia giving rise to tides of great height.

The Bay of Fundy, noted for its dense fogs and high tides, extends nearly 200 hundred miles inland from the ocean. Its shores are generally high and rocky, rising like great walls against the sea; causing dangerous bores in the upper reaches. The bore is the first rush of the incoming tide. In some places the shore presents a very bare appearance at low tide owing to its long expanse of mud flats.

Yarmouth, located near the southern extremity of Nova Scotia, at the mouth of the Bay, has long been noted for its shipping and ship-building. Although its tides are not so enormous as at points farther up the bay, they are sufficiently high to astonish a stranger, who at low tide cannot see sufficient water to float the vessels made fast to the docks. At the entrance of the bay, the tide rises to the height of eighteen feet; and as Yarmouth is virtually at the entrance, very considerable tides may be expected.

At St. John, about one hundred miles farther up the bay, coasting schooners float in twenty-five feet of water, where six hours later they are high and dry, their decks ten to fifteen feet below the level of the wharves. It is here that the celebrated reversing fall is located. It is caused by a rock barrier, over which the fresh water of the river flows as it is discharged into the harbor through the narrow rocky gorge forming beautiful waterfalls of about fifteen feet when the tide is out; but when the tide turns the salt water of the incoming tide gathers force and rises much above the barrier, and the flood is forced backward, causing a reversal of the falls with the water actually pouring upstream.

Farther up the bay we have Cape Blomidon, a mass of trap rock on red sandstone; part of the North Mountains range rising at Look-off, a nearby point, to an altitude of 700 feet. At the Cape this promontory is about 500 feet high. North of Blomidon we find Cape Sharp, the opposite rocky barrier, some three miles distant, which, like Blomidon, has successfully withstood the impetuous onslaught of the roaring tides for untold ages. To

beat down through this "gut" as it is called, against wind and tide, would indeed be a perilous adventure. Through the narrow passage the incoming water pours with great violence, flowing in an easterly direction until the entire Basin of Minas has become an inland sea. The enormous volume and great force of this tide indicates in some measure the tremendous power of the tidal forces.

Near the junction of Minas Basin and the river Avon are located Kingsport, Horton, and Hantsport, ship-building towns. Here ships of considerable size are readily repaired in front of a wharf which serves as a natural dry-dock when the tide is out.

FIG. 1.

Negative by Edson Graham.

Windsor, tide out.

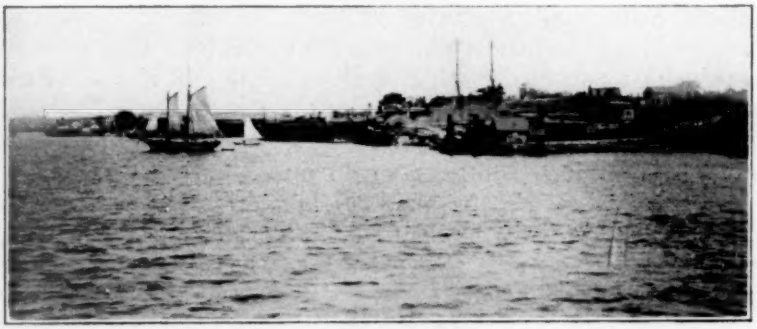
Windsor, located upon the river Avon, some ten miles from Minas Basin, is a picturesque old town, with good streets and beautiful drives leading into the surrounding country. It has long been noted for the excellent quality of gypsum which is mined there and exported to points on the Atlantic coast, much coming to Philadelphia. Windsor is a good point from which to view and study the tides, which are over thirty feet high, although at Halifax, about thirty miles distant on the Atlantic coast opposite, they rarely exceed seven feet.

Some forty miles farther up the Basin of Minas, the Shubanacadie River enters the bay at Maitland. This river is also comparatively small when the tide is out, but the high-water mark is clearly shown about forty feet up on its steep rocky easterly side. It is said to be the highest tide-water river in the world.

About twelve miles farther up the bay, near the lower village of Truro, the bay is only about half a mile wide, with no salt water at low tide. A mile farther, the high ground on either side approaches sufficiently near to allow a bridge to be readily built. After passing the bridge, a basin about a mile in length is reached. This basin is fed with fresh water by the North River and Salmon River, both small streams. Before the bridge was erected, ships of small size were built here and floated down to deeper water when the tide was in.

At Moncton, New Brunswick, the Petitcodiac River, at low tide, is only a narrow channel bordered with wide mud-banks,

FIG. 2.



Negative by Edson Graham.

Windsor, tide in.

which reach from the shore to the narrow stream of fresh water. When the incoming tide of the northern arm of the Bay of Fundy reaches the narrow part of the river, the water is forced back with great violence and a tidal wave, or "bore," from three to six feet high is formed. At this point the tide sometimes reaches the enormous height of sixty feet.

The first intimation a visitor has of the incoming tide, is a dull, rumbling sound, like that of a distant waterfall combined with the rolling sound of an approaching train. As the tide approaches the sound increases, until finally the "bore" is seen, coming as a huge rolling wave, from one to six feet high, slightly convex in front, owing to the shore friction. The speed of this advance wave, or first rush, is described as that of a race horse; and indeed it is such as to rapidly wear away the mud banks in the channel bed, giving a decidedly red color to the water.

SOME MODIFICATIONS OF PLATINUM PRINTS.

BY
JOHN BARTLETT,
Editor, Bulletin of Photography.

PAINTERS seem to prefer a print in black and white with intermediate gradation, asserting that such tones are more suggestive from their purity of color range than any other tints.

Rich engraving is certainly capable of translating the color of the original painting better than the most skilfully executed colored lithograph, chromo, or even a well-done three-color-process print, and so the painter is always more charmed by a beautiful black and white platinum than he is by a sepia or other tone print made in the same medium. But photographers and the public in general prefer sepia or brown tones.

It may be that the really inadequate black of a bromide of silver print (velox) is the cause of the preference.

We have heard many maintain that there is practically no difference between the blacks of platinum and bromide, but the difference is generally acknowledged, when, for comparison, one is placed against the other. However as the demand for other than platinum black is predominant, it is necessary to modify the tone to suit the prevalent taste.

One thing is essential to secure the beautiful "black" of the platinum and that is the employment of perfectly fresh platinum paper. We recently came across a lot of stale platinum paper, which the owner declared was fit only to go to the reducers for the extraction of the valuable metal, or to be used as a tinted background in artistic mounting. At our request he allowed us to experiment with some of it before its ultimate condemnation.

This paper presented anything but a promising aspect, being much tinted by age. With normal oxalate development it gave weak flat images scarcely differentiating themselves from the ground of the paper. We next tried what effect an alkaline development would have. Carbonate of soda at normal temperature (about 70°) was employed. The development proceeded somewhat rapidly and gave better tones than with oxalate, but invariably the image lacked sharpness and distinctness; the

reduced platinum seeming to spread over into the margins of the white ground. Outside those limits the ground was pure; the black part of the image also partook of a rusty appearance. Dilution or concentration of developer seemed to make but little material improvement, nor did ammonium or potassium better conditions.

By experimenting both in printing and in developing we hit upon a method of improvement in respect to sharpness as well as color, but not to the extent as far as color is concerned as with fresh paper, sufficient, however, to make very presentable results comparing most favorably with the bromide print.

The exposures were somewhat shortened (about one-third less than with the fresh paper) and the printing was done in the sun.

The alkaline bath should be constituted as follows: Saturated solution of sodium carbonate diluted with equal volume of water, to which add one-eighth the bulk of a saturated solution of common alum. The slight milkiness produced does not interfere with the action on the print, but it is best to have considerable solution in the tray.

The development is effected by applying the print face down to the surface so as to avoid wetting the back of the print which interferes at the part with the intensity of the tone. Avoid, however, the formation of air-bells on the surface. Allow the paper to remain in contact with the developer only a few seconds (not more than fifteen seconds), as the object is to keep the impression on the surface. Raise the print up without sliding after the expiration of the time and place it upon a sheet of glass, noting the progress and extent of the action. The slight excess of fluid on the surface may be directed to any spot needing attention.

When the proper intensity is reached place at once in the acid bath (1 : 50) and let it remain there for five minutes or more, then transfer to another acid bath and wash as usual. Do not fail to apply first the acid baths before washing.

The tones obtained by this method will be found most satisfactory. The black has a slight tendency to blue or purple.

Another plan for utilizing stale platinum (published about a year ago), consists in the use of a small percentage of neutral chromate of potassium. We are thus enabled to secure

quite brilliant prints from very old paper. The samples we experimented with dated three years back. The quantity of the chromate of potash should not exceed one-half grain to the fluid ounce of oxalate developer, which is used cold. Care should be taken not to confound the chromate with the bichromate, as the action of the latter salt is too energetic, eating away the half tones of the picture.

The chromate (neutral salt) may also be used in less quantity and perferably in a five per cent. solution as a retarder or restrainer for over printed fresh paper platinum proofs. It gives the necessary contrast and prevents flatness. A couple of drops (5 per cent. solution) to the ounce of developer is quite sufficient. The developer here also should be used cold, not over 60° or 70°.

Various means have been suggested for improving the condition of under-printed platinum proofs. One plan is to first soak the print in pure water and then evenly spread glycerin over the face to be followed by a weak acid bath of chloride of gold. This of course after development.

Dr. Vogel's method with chloroplatinite of potassium did not give me favorable results. The tone was too bistre or rusty looking.

Dr. Liesegang's plan is much to be preferred. After the developed print has passed through the acid baths, and has been thoroughly washed, it is placed in a bath composed of hydroquinone, citric acid and water, to which a few drops of a 60 grain solution of silver nitrate are added—which acts as an intensifier. The slight clot formed on addition of the silver does no harm. On completion of the intensification, wash the print and immerse for five minutes or more in a weak hyposulphite of soda bath.

The deposition of the silver on the platinum basis may now to advantage be followed by the formula recommended by Dr. Vogel. Gold and uranium can also be employed with prints so intensified.

A gold bath with sulphocyanide of potassium (similar to the well-known combined bath used in toning silver prints) may be advantageously employed to modify further the tone. The color so obtained is a rich bluish black.

The print treated with uranium nitrate followed by ferricyanide of potassium gives quite pleasing brown tones. The

question of permanency of such prints might be agitated on account of the presence of the silver salt.

The ordinary black developed (normal) platinum print has always been regarded as permanent as the platinum black itself, and the fading sometimes experienced is blamed on faulty manipulation, to the presence of the traces of iron in the paper, which persist despite the application of the acid baths with a view of its elimination. But while we are not prepared to positively say that modified platinum prints are as permanent as untouched prints, we might venture to affirm that they have as good a chance to escape the vicissitudes of things as sepia platinums where mercury is present either in coating or applied to the developer.

PRESENT CONDITION OF THE COUNTRY'S FOREST RESOURCES.

FEW people have anything like a clear idea of the amount of forest wealth left in this country. Those who think at all about this natural resource which has assisted in material development since the landing of the first settlers are usually too much influenced by the condition of that particular State or section in which they are most familiar.

If they live in a much deforested or a treeless region, the people usually imagine that the country's timber supply is even more limited than is actually the fact; on the other hand, with those whose homes are located in a section where a pinch in timber has not been experienced, the feeling is likely to be altogether the other way, and some become so indifferent at times as to think that there is really not much reason to worry about a timber problem. Both can profit by a reading of the actual facts.

The forests of the United States now cover about 550 million acres, or about one-fourth of the land of the whole country. The original forests covered not less than 850 million, acres, or nearly one-half.

The forests owned by the Government cover one-fourth of the total forest area, and contain one-fifth of all timber standing. Forests privately owned cover three fourths of the area, and contain four-fifths of the standing timber. Besides having three times the area and four times the forests, the timber land privately owned is generally more valuable.

Forestry, or conservative lumbering, is practiced on 70 per cent. of the forests publicly owned and on less than one per cent. of the forests privately owned. This covers the country's forest resources as they stand to-day. Senator Smoot, chairman of the section of forests of the National Conservation Commission, in outlining the future has said:

"By reasonable thrift, we can produce a constant timber supply beyond our present need, and with it conserve the usefulness of our streams for irrigation, water supply, navigation, and power.

"Under right management, our forests will yield over four times as much as now. We can reduce waste in the woods and in the mill at least one-third, with present as well as future profit. We can perpetuate the naval stores industry. Preservative treatment will reduce by one-fifth the quantity of timber used in the water or in the ground. We can practically stop forest fires at a total yearly cost of one-fifth the value of the standing timber burned each year, not counting the young growth.

"We shall suffer for timber to meet our needs, until our forests have had time to grow again. But if we act vigorously and at once, we shall escape permanent timber scarcity."

CHEMICAL SECTION

(Stated meeting held Thursday, February 4, 1909.)

CALCIUM ALUMINATES; THEIR EFFECT ON MORTARS.

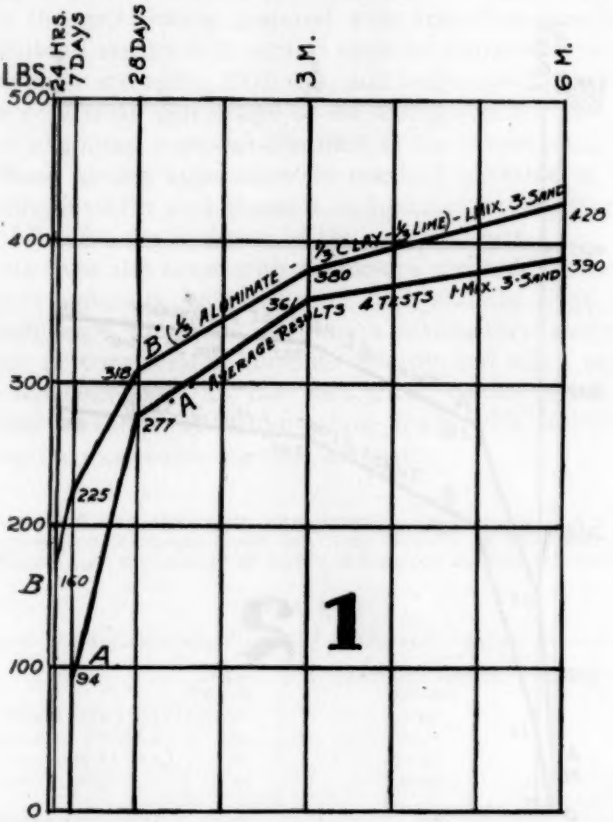
BY
HENRY S. SPACKMAN.

THE effect of the addition of separately prepared calcium aluminate to the ordinary mortars used in the building trade has been carefully studied by the writer in the course of an extensive investigation covering the synthetic production of Portland or similar cements; that is, the method of making such cements by mechanically incorporating the ingredients without combining all the argillaceous and calcareous elements by calcination. This investigation grew out of striking results obtained some years ago in investigating the amount of material in Portland cement actually active in producing the hardening of the mortar.

When once undertaken, the scope of this investigation into the production of cement by synthetic methods broadened and became so involved that it has, up to the present time, included a vast amount of work, extending back over a number of years. For instance, the reactions of the single cement elements, such as lime and silica were studied under various physical and chemical conditions, and a large number of two-element compounds investigated, such as the calcium silicate and calcium aluminate series. Many striking incidental results were obtained but these are overshadowed by the industrial and theoretical importance of the demonstration by this work of the practicability of producing reliable cements by the incorporation of only a small percentage of accelerating or energizing material with mixtures of ordinary lime and shale, clay or other silicious material in finely divided condition.

We noted the effect of the addition of small quantities of calcium aluminate accelerator to mixtures of various proportions of hydrated lime and finely ground sand and of lime and ordinary

field clay or shale which were used in their natural condition in which they possessed no hydraulic or cementitious qualities. Not only were the clay and shale alone devoid of binding properties,



Line A shows the average results obtained on a number of tests made with the California shale described in the detailed tests and covers variations in the amount of lime added and the percentage of aluminate, which varies from 7 to 12 per cent.; the lime varying from 29 to 45 per cent. of the mass. The tests given are the average breaking strength of the briquettes, mixed one part of the mixture of clay, lime, accelerator and retarder and three parts of standard sand, by weight. *Line B* shows graphically the tests obtained on a mixture of one-third shale, one-third hydrated lime and one-third aluminate. This mixture was mixed with three parts, by weight, of sand. The briquettes in each case were one day in air, balance of time in water.

but mixtures of these with lime gave no hydraulic qualities and only insignificant strengths, but with the addition of calcium aluminate decided hydraulic and cementitious qualities were developed in these previously practically inert mixtures. Practically any setting time desired could be secured by proportioning

the amount of the accelerator and of retarding material, such as calcium sulphate, and so forth. The strength of mortar made with such mixtures can also be increased considerably

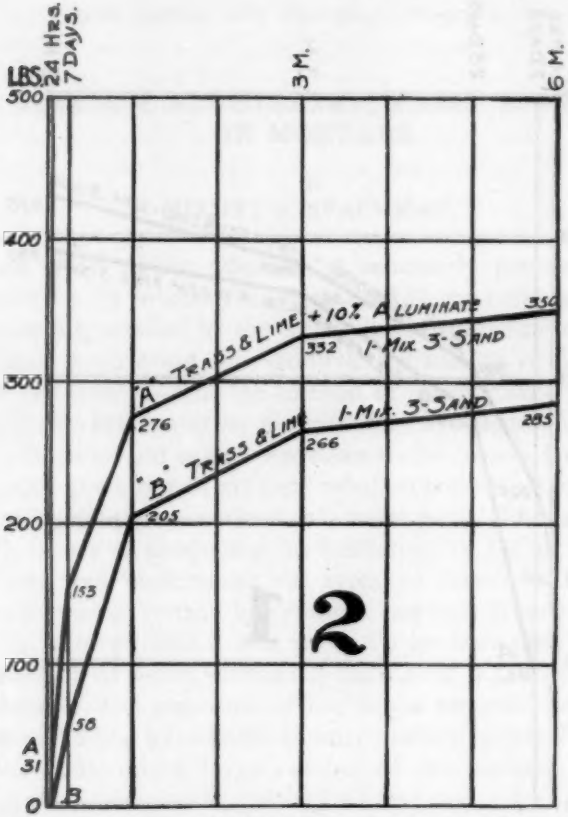


FIG. 2 shows the average results obtained on various tests of mixtures of trass, hydrated lime and calcium aluminates, the mixtures varying from thirty parts of lime to sixty parts of trass, to fifty parts of lime to fifty parts of trass, to which was added 10 per cent. calcium aluminate. The tests show the strength obtained from briquettes made from the above mixture to which were added three parts of standard sand, briquettes being one day in air, balance of time in water. *Line A* shows the average strength of the trass-lime mixtures to which aluminate has been added. *Line B* shows the average strength of the trass-lime mixtures without the addition ot aluminate.

above Portland cement strengths at earlier periods by using more of the accelerator.

The experiments show that very valuable results were secured by using the accelerator with hydrated lime alone; the addition of small proportions of calcium aluminate to hydrated lime gave

valuable wall-plaster compositions having quick hardening and increased spreading properties and very considerable strength in air at short periods, while larger proportions of accelerator gave strongly hydraulic compositions of greater strength. Incorporation of the accelerating material with trass-lime compositions gave striking results and natural cements are greatly improved in their early strengths, hardness, and resistance to abrasion by the use of a small percentage of the aluminate.

The aluminate compositions used in the investigation varied from those having approximately one-half molecule of lime to one molecule of the acid elements to mixtures having three molecules of lime to one molecule of the acid elements.

Tests were also made with aluminates prepared from bauxite and other materials, such as kaolin, high alumina slags, etc., all of which were found to work in a satisfactory manner, the presence of considerable amounts of iron and silica not being found objectionable. In the tests given below in order that they may be comparative, only those made with aluminate approaching the monocalcic formula are given.

TESTS SHOWING THE EFFECT OF THE ADDITION OF CALCIUM ALUMINATE TO MIXTURES OF HYDRATED LIME AND ARGILLACEOUS OR SILICIOUS MATERIAL WITHOUT ANY TREATMENT OF THESE MATERIALS BEYOND PULVERIZATION.

ANALYSES.

Shale from California, Hydrated Lime, and Calcium Aluminate.

	Shale. Per cent.	Calcium aluminate. Per cent.	Hydrated lime. Per cent.
Silica (SiO_2) Al_2O_3	69.02	1.16	1.02
Alumina (Al_2O_3)	5.31	62.41	.42
Iron oxide (Fe_2O_3)	2.25	4.51	
Lime (CaO)	6.22	31.46	73.58 = 96.87 $Ca(OH)_2$
Magnesia (MgO)	3.12	.72	1.12
Loss on ignition	11.96	.02	23.66

The shale was exceedingly fine grained, no silica being present as sand. A mixture was made from these materials in the following proportions:

45 parts hydrated lime,
40 parts shale,
12 parts aluminate,
3 parts plaster of Paris.

This mixture when tested in the usual manner for physical properties gave the following results:

Tensile Tests.—One part mixture, 3 parts Ottawa sand; 1 day in air, balance of time in water. Setting time: initial set, 2 hours; final set, 4 hours.

48 hours.	7 days.	28 days.	3 months.
80 pounds	100 pounds	300 pounds	370 pounds
75 pounds	100 pounds	320 pounds	380 pounds
80 pounds	120 pounds	300 pounds	390 pounds
av. 78 pounds	106 pounds	307 pounds	380 pounds

Another mix was made from the above materials in the following proportions:

59 parts shale,
29 parts hydrated lime,
12 parts aluminate.

This mixture when tested for tensile strength in the usual manner gave the following results:

Tensile Test.—One part mixture, 3 parts Ottawa sand, 1 day in air, balance of time in water.

7 days.	28 days.	3 months.	6 months.
100 pounds	250 pounds	350 pounds	415 pounds
110 pounds	265 pounds	335 pounds	320 pounds
105 pounds	260 pounds	340 pounds	405 pounds
av. 105 pounds	259 pounds	342 pounds	390 pounds

Another mixture was made of the same materials in the proportions of:

⅓ shale,
⅓ hydrated lime,
⅓ aluminate.

This material when tested in the usual manner gave the following results Setting time: initial, 35 minutes, final, 1 hour and 15 minutes. Soundness: air, O.K.; cold water, O.K.; steam, O.K.; boiling, O.K.

Tensile Tests.—One part mixture, 3 parts Ottawa sand, 1 day in air, balance of time in water.

24 hours.	7 days	28 days.	3 months.	6 months.
150 pounds	220 pounds	300 pounds	360 pounds	450 pounds
170 pounds	225 pounds	330 pounds	410 pounds	410 pounds
160 pounds	230 pounds	325 pounds	370 pounds	425 pounds
av. 160 pounds	225 pounds	318 pounds	380 pounds	428 pounds

Another test was made on the same materials using 7 parts aluminate, 45 parts lime, 45 parts clay and 3 parts plaster. This gave the following physical test:

Setting time: initial set, 2 hours; final set, 4 hours.

Tensile Tests.—One day in air, balance of time in water.

neat.	7 days.	1 cement, 3 sand.
65		85
70		90
av. 68		av. 88

neat.	28 days.	1 cement, 3 sand.
225		320
245		350
av. 235		av. 335

(See Fig. 1 and legend, page 187.)

TEST OF CLAY FROM WISCONSIN HYDRATED LIME AND CALCIUM ALUMINATE.

	Clay. Per cent.	Aluminate. Per cent.	Hydrated lime. Per cent.
Silica (SiO_2)	68.84	1.16	1.02
Alumina (Al_2O_3)	12.07	62.41	.42
Iron oxide (Fe_2O_3)	7.17	4.51	
Lime (CaO)	1.16	31.46	$73.58 = 96.87$ $Ca(OH)_2$
Magnesia (MgO)	1.37	.72	1.12
Loss on ignition	9.54	.02	23.66

This was rather coarse-grained field clay containing some sand.
A mixture of the above materials was made in the following proportions:

35 parts clay,
55 parts hydrated lime,
7 parts aluminate,
3 parts plaster of Paris.

This material when tested in the usual manner gave the following results:
Setting time: initial, 1 hour and 30 minutes; final, 4 hours and 30 minutes.

Water Exposure.

7 days.	28 days.	3 months.
85 pounds	140 pounds	100 pounds
95 pounds	130 pounds	120 pounds
100 pounds	145 pounds	120 pounds
av. 93 pounds	138 pounds	113 pounds

Air Exposure.

1 cement, 3 sand.

7 days.	28 days.
100 pounds	100 pounds
130 pounds	110 pounds
115 pounds	110 pounds
av. 115 pounds	107 pounds

A mixture was then made from finely ground sandstone, hydrated lime, and calcium aluminate, analyzing as follows:

	Sandstone. Per cent.	Calcium aluminate. Per cent.	Hydrated lime. Per cent.
Silica (SiO_2)	90.26	1.15	1.02
Alumina (Al_2O_3) + Iron oxide (Fe_2O_3)	3.82	62.41	.42
Lime (CaO)	.60	31.46	$73.58 = 96.87$ $Ca(OH)_2$
Magnesia (MgO)	.42	.72	1.12
Loss on ignition	.90	.02	23.66

The sandstone was ground to a fineness of 92 per cent. on No. 200 sieve.
These materials were mixed in the following proportions:

35 parts ground sand,
55 parts hydrated lime,
10 parts aluminate,

when treated in the usual manner gave the following physical tests:

Setting time: initial, 2 hours and 50 minutes; final, 8 hours.

Tensile Tests.—One part mixture, 3 parts Ottawa sand, 1 day in air, balance of time in water.

7 days.	28 days.	3 months.
75 pounds	50 pounds	100 pounds
70 pounds	60 pounds	120 pounds
75 pounds	50 pounds	120 pounds
av. 72 pounds	53 pounds	113 pounds

Tensile Test.—One part mixture, 3 parts Ottawa sand, air exposure.

7 days.	28 days.
95 pounds	160 pounds
110 pounds	150 pounds
100 pounds	150 pounds
av. 101 pounds	153 pounds

TESTS SHOWING EFFECT OF ADDITION OF CALCIUM ALUMINATE TO TRASS AND LIME MORTARS.

The materials used in the investigation were Trass from D. Servas & Sohne Koln a Rhein, Germany, high calcium hydrated lime and calcium aluminate made in the Laboratories of the Henry S. Spackman Engineering Co., Philadelphia, Pa.

These materials were found to contain:

	Trass. Per cent.		Hydrated lime. Per cent.
Silica (SiO_2)	55.62	Silica (SiO_2)	1.02
Alumina (Al_2O_3)	22.06	Alumina (Al_2O_3) }	.42
Iron oxide (FeO)	1.64	Iron oxide (Fe_2O_3) }	
Lime (CaO)	1.82	Lime (CaO) $73.58 = 96.87$ $Ca(OH)_2$	
Magnesia (MgO)	.54	Magnesia (MgO)	1.12
Soda (Na_2O)	6.01	Loss on ignition	23.66
Potash (K_2O)	1.71		
Loss on ignition	10.16		

Calcium Aluminate.

Silica (SiO_2)	3.40 per cent.
Alumina (Al_2O_3)	45.16 per cent.
Iron oxide (Fe_2O_3)	12.80 per cent.
Lime (CaO)	35.40 per cent.
Magnesia (MgO)	2.72 per cent.
Loss on ignition	.64 per cent.

Mixture, 10 parts aluminate, 30 parts hydrated lime, 60 parts trass.

Tensile Test.—One part mixture, 3 parts standard Ottawa sand, 24 hours in air, balance of time in water, in pounds per square inch.

24 hours.	7 days.	28 days.	3 months.	6 months.
25 pounds	140 pounds	280 pounds	310 pounds	310 pounds
25 pounds	145 pounds	290 pounds	315 pounds	320 pounds
25 pounds	150 pounds	285 pounds	295 pounds	330 pounds
av. 25 pounds	145 pounds	285 pounds	307 pounds	320 pounds

Mixture, 10 parts aluminate, 45 parts hydrated lime, 45 parts trass.
Tensile Tests.—Twenty-four hours in air, balance of time in water in pounds per square inch.

Neat.

24 hours.	7 days.	28 days.	3 months.	6 months.
65 pounds	200 pounds	230 pounds	300 pounds	300 pounds
75 pounds	200 pounds	250 pounds	320 pounds	310 pounds
av. 70 pounds	200 pounds	240 pounds	310 pounds	305 pounds

One Part Mixture to Three Parts Standard Sand.

24 hours.	7 days.	28 days.	3 months.	6 months.
55 pounds	205 pounds	310 pounds	380 pounds	380 pounds
60 pounds	210 pounds	300 pounds	360 pounds	400 pounds
av. 58 pounds	208 pounds	305 pounds	370 pounds	390 pounds

TENSILE TEST OF TRASS AND LIME WITHOUT THE ADDITION OF ALUMINATE

Mixture, 1 part hydrated lime, 2 parts trass.
Tensile Tests.—One part mixture, 3 parts Standard Ottawa Sand.

24 hours.	7 days.	28 days.	3 months.	6 months.
no strength	60 pounds	210 pounds	250 pounds	280 pounds
no strength	60 pounds	200 pounds	280 pounds	285 pounds
no strength	50 pounds	205 pounds	270 pounds	290 pounds
	av. 58 pounds	205 pounds	266 pounds	285 pounds

(See Fig. 2 and legend, page 188.)

TESTS MADE TO SHOW THE EFFECT OF THE ADDITION OF CALCIUM ALUMINATE TO HYDRATED LIMES.

ANALYSES OF LIMES AND CALCIUM ALUMINATE.

	Calcium aluminate. Per cent.	High calcium lime. Per cent.	Magnesian lime. Per cent.
Silica (SiO_2)	9.14	2.77	2.30
Alumina and Iron Oxide (R_2O_3)	56.80	0.99	0.92
Lime (CaO)	31.32	70.67	43.34
Magnesia (MgO)	.80	1.38	29.46
Loss on ignition	2.08	24.10	24.14

The aluminate was mixed with the high calcium hydrate in proportion to 5 parts by weight aluminate, 93 parts hydrated lime and 2 parts plaster of Paris.
Tensile Test.—One part mix as above to 3 parts by weight Standard Ottawa Sand in pounds per square inch—air exposure.

7 days.	28 days.	3 months.	9 months.	12 months.
45 pounds	125 pounds	120 pounds	130 pounds	155 pounds
50 pounds	130 pounds	120 pounds	130 pounds	180 pounds
55 pounds	120 pounds	115 pounds	130 pounds	180 pounds
av. 50 pounds	125 pounds	118 pounds	130 pounds	172 pounds

The aluminate was mixed with high calcium hydrate as above in proportion 10 parts aluminate, 88 parts hydrated lime, 2 parts plaster of Paris.

Tensile Test.—One part mixture, 3 parts Standard Ottawa Sand in air, pounds per square inch.

7 days	28 days.	3 months.	9 months.	12 months.
85 pounds	170 pounds	150 pounds	120 pounds	200 pounds
90 pounds	150 pounds	185 pounds	135 pounds	175 pounds
70 pounds	145 pounds	120 pounds	120 pounds	170 pounds
av. 82 pounds	155 pounds	152 pounds	125 pounds	182 pounds

The aluminate was mixed with high magnesian hydrated lime as above in proportion by weight of 10 parts aluminate, 88 parts hydrated lime, 2 parts plaster of Paris.

Tensile Test.—One part mixture, 3 parts standard sand in air.

7 days.	28 days.	3 months.	9 months.	12 months.
70 pounds	155 pounds	155 pounds	120 pounds	165 pounds
65 pounds	130 pounds	165 pounds	125 pounds	190 pounds
70 pounds	120 pounds	170 pounds	115 pounds	210 pounds
av. 68 pounds	135 pounds	163 pounds	120 pounds	188 pounds

The aluminate was mixed with high magnesian hydrated lime in proportion by weight of 5 parts aluminate, 93 parts lime, 2 parts plaster of Paris.

Tensile Test.—One part mixture, 3 parts standard sand in air.

7 days.	28 days.	3 months.	9 months.	12 months
35 pounds	76 pounds	65 pounds	125 pounds	145 pounds
35 pounds	80 pounds	95 pounds	100 pounds	195 pounds
40 pounds	80 pounds	110 pounds	140 pounds	140 pounds
av. 37 pounds	78 pounds	90 pounds	122 pounds	170 pounds

Another test was made using an aluminate prepared after we had become more familiar with its manufacture, mixed in proportions of 10 parts aluminate, 88 parts high calcium hydrated lime, 2 parts plaster of Paris.

Tensile Test.—One part mixture, 3 parts standard Ottawa sand, in air.

48 hours.	7 days.	28 days.	3 months.	6 months.
49 pounds	94 pounds	96 pounds	120 pounds	130 pounds
61 pounds	118 pounds	94 pounds	130 pounds	135 pounds
63 pounds	91 pounds	92 pounds	125 pounds	145 pounds
av. 61 pounds	101 pounds	94 pounds	125 pounds	136 pounds

A test was then made using the last aluminate to determine the hydraulic properties. A mixture of 10 parts aluminate and 90 parts hydrated lime, gave when tested in the usual manner, 1 part mixture, 3 parts standard sand, 1 day in air, balance of time in water.

7 days.	28 days.	3 months.
5 pounds	30 pounds	50 pounds
5 pounds	35 pounds	60 pounds
5 pounds	40 pounds	50 pounds
av. 5 pounds	35 pounds	53 pounds

A mixture of 17 parts aluminate, 3 parts plaster of Paris, 80 parts hydrated lime.

Tensile Test.—One part mixture, 3 parts standard sand, 1 day in air, balance of time in water.

7 days.	28 days.	3 months.
65 pounds	120 pounds	100 pounds
70 pounds	90 pounds	100 pounds
50 pounds	105 pounds	130 pounds
av. 62 pounds	105 pounds	110 pounds

(See Fig. 3 and legend, page 197.)

TESTS MADE TO SHOW THE EFFECT OF ADDITION OF CALCIUM ALUMINATE TO NATURAL CEMENTS.

ANALYSES.

	Natural cement. Per cent.	Aluminate. Per cent.	Hydrated lime. Per cent.
Silica (SiO_2)	22.22	1.16	1.02
Alumina (Al_2O_3)	9.99	62.41	0.42
Iron oxide (Fe_2O_3)	2.63	4.51	
Lime (CaO)	54.72	31.46	73.58 = 96.87 $Ca(OH)_2$
Magnesia (MgO)	2.92	0.72	1.12
Loss on ignition	5.74	0.02	23.66

The natural cement was received in the form of clinker and to this was added 5 per cent of aluminate, 5 parts hydrated lime. The material was then ground and 2 parts plaster of Paris incorporated therewith. This material when tested according to the standard specifications for cement gave the following results:

Fineness: passing No. 100 sieve, 100 per cent.; passing No. 200 sieve, 91 per cent.; Setting time: initial set, 1 hour; final set, 1 hour and 30 minutes.

Tensile Test.—One part mixture, 3 parts standard Ottawa sand. In pounds per square inch, 1 day in air, balance of time in water.

24 hours.	7 days.	28 days.	3 months.	6 months.
205 pounds	350 pounds	450 pounds	495 pounds	470 pounds
210 pounds	360 pounds	460 pounds	515 pounds	545 pounds
195 pounds	360 pounds	460 pounds	550 pounds	495 pounds
av. 203 pounds	358 pounds	458 pounds	520 pounds	503 pounds

The cement was then mixed in the proportions of 80 parts clinker, 10 parts calcium aluminate, 10 parts hydrated lime, 2 parts plaster of Paris.

Tensile Test.—One part mixture, 3 parts standard Ottawa sand, in pounds per square inch, 1 day in air, balance of time in water.

7 days.	28 days.	3 months.	6 months.
375 pounds	500 pounds	515 pounds	595 pounds
380 pounds	490 pounds	520 pounds	420 pounds
370 pounds	510 pounds	545 pounds	640 pounds
av. 375 pounds	500 pounds	527 pounds	552 pounds

The above tests were then repeated on commercial samples of natural cement to which was added the calcium aluminate and lime, six different samples being tested. These were mixed in the proportions of 90 parts cement, 5 parts calcium aluminate, 5 parts lime. To this mixture 2 parts plaster of Paris was added. The average results obtained of this series of tests are as follows:

Fineness: passing No. 100 sieve, 99 per cent.; passing No. 200 sieve, 89 per cent.; Setting time: initial set, 1 hour and 14 minutes; final set, 2 hours and 9 minutes.

Tensile Test.—One part mixture, 3 parts standard Ottawa sand, in pounds per square inch, 1 day in air, balance of time in water.

Average of Fifteen Tests.

24 hours.	7 days.	28 days.	3 months.
A–145 pounds	222 pounds	304 pounds	463 pounds
B–141 pounds	217 pounds	312 pounds	404 pounds

The same cements were then tested with the addition of 10 parts aluminate, 10 parts hydrated lime, 2 parts of plaster of Paris being added. The average of these tests is as follows:

Fineness: passing No. 100 sieve, 99 per cent.; passing No. 200 sieve, 91 per cent.; Setting time: initial set, 54 minutes; final set, 1 hour and 40 minutes.

Tensile Test.—One part mixture, 3 parts standard Ottawa sand. In pounds per square inch. One day in air, balance of time in water.

Average of Six Tests.

24 hours.	7 days.	28 days.	3 months.
C–155 pounds	229 pounds	329 pounds	437 pounds

Average of Six Sand Tests Without Treatment.

24 hours.	7 days.	28 days.	3 months.
43 pounds	88 pounds	173 pounds	237 pounds

(See Fig. 4 and legend, page 199.)

In view of the fact that the investigation is still in progress, no specific conclusions have been drawn by the writer as to the exact manner in which the addition of the aluminate produces the striking results shown by the tests given.

The tests quoted, however, are typical and are borne out by the many other tests on similar materials made in the course of the extended investigations of the subject by the writer, but the fact that no explanation of how the aluminate acts is at present forthcoming is not a bar to the utilization of cement produced by this process. This is evinced by the fact that after many years of use and careful study the exact reactions taking place and compounds formed during the induration of Portland cement are still unknown. This is due to the fact that it is extremely difficult to isolate and identify hydraulic compounds which undergo decomposition or alteration on contact with water and to the fact that the crystals formed by the induration of cements are largely submicroscopic.

Considering the commercial applications and technical use of the results shown by the preceding tests, that is, the indication that the addition of a small percentage of calcium aluminate gives to materials possessing the property of hardening on being mixed with water, greatly increased strength, we will consider first the application of this discovery to limes.

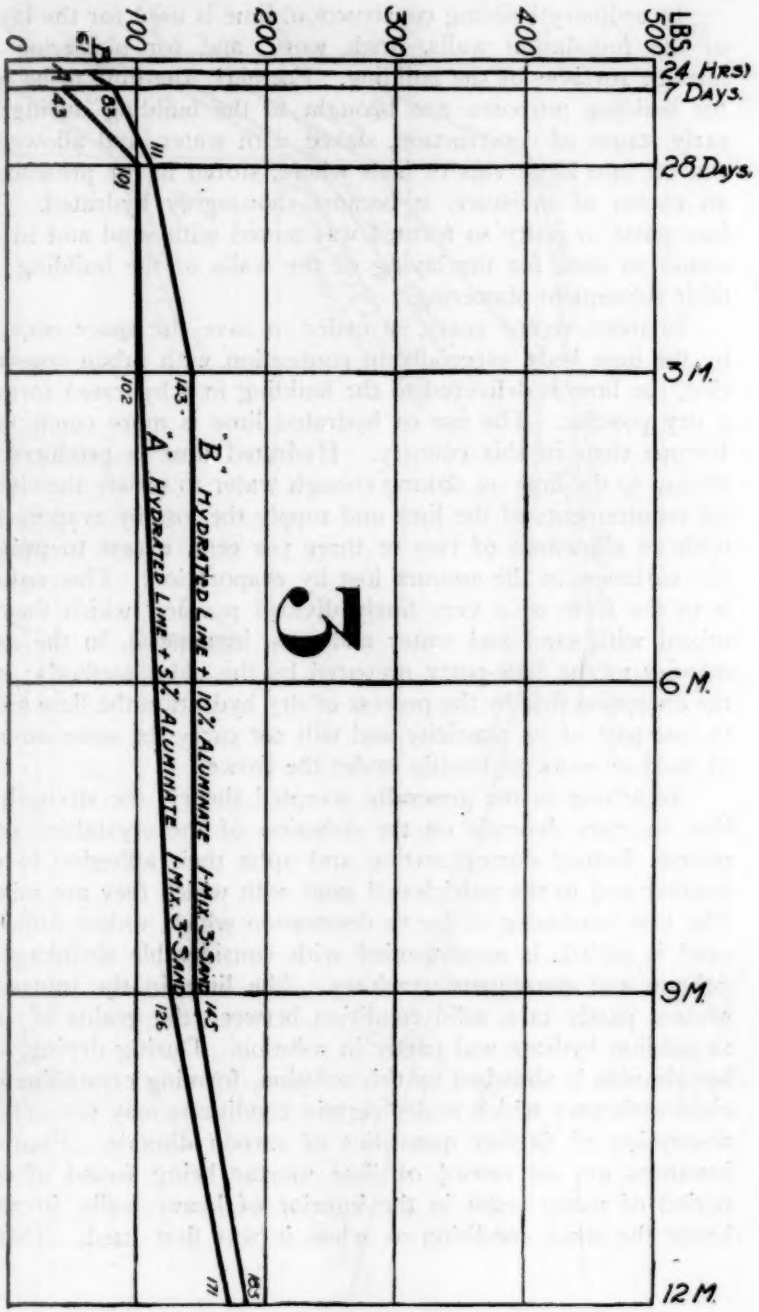


FIG. 3 shows the average strength obtained from a number of tests made on hydrated limes to which 5 and 10 per cent. aluminate has been added. Both high calcium and dolometic limes were tested and the results from these grouped together. *Line A* shows the tensile strength developed by hydrated limes to which 5 per cent. calcium aluminate was added, mixed one part mixture to three parts standard sand. *Line B* shows the strength developed by the same materials when 10 per cent. calcium aluminate was added, mixed one part mixture to three parts standard sand.

In ordinary building construction, lime is used for the laying of the foundation walls, brick work, and for plastering the interior surfaces of the building. Formerly the lime to be used for building purposes was brought to the building during the early stages of construction, slaked with water, and allowed to run off into large vats or beds where, stored in the presence of an excess of moisture, it became thoroughly hydrated. The lime-paste or putty so formed was mixed with sand and in this condition used for the laying of the walls of the building and their subsequent plastering.

In more recent years, in order to save the space occupied by the lime beds, especially in connection with urban construction, the lime is delivered to the building in a hydrated form as a dry powder. The use of hydrated lime is more common in Europe than in this country. Hydrated lime is produced by adding to the lime on slaking enough water to satisfy the chemical requirements of the lime and supply the loss by evaporation, with an allowance of two or three per cent. excess to provide for variation in the amount lost by evaporation. This reduces it to the form of a very finely divided powder, which may be mixed with sand and water and acts, in general, in the same manner as the lime-putty prepared by the older methods; with the exception that by the process of dry hydration the lime seems to lose part of its plasticity and will not carry the same amount of sand or work as readily under the trowel.

According to the generally accepted theory, the strength of lime mortars depends on the cohesion of the crystalline compounds formed during setting and upon their adhesion to one another and to the particles of sand with which they are mixed. The first hardening is due to desiccation which, unless sufficient sand is added, is accompanied with considerable shrinkage in volume and consequent cracking. The lime in the mortar is present partly in a solid condition between the grains of sand as calcium hydrate and partly in solution. During drying, carbon dioxide is absorbed by this solution, forming crystalline calcium carbonate which under certain conditions may prevent the absorption of further quantities of carbon dioxide. Frequent instances are on record of lime mortar being found after a period of many years in the interior of heavy walls, in absolutely the same condition as when it was first used. This is

FIG. 4 shows the results obtained by the addition of calcium aluminate to natural cements. *Line A* shows the average strength of six commercial samples of natural cement tested one part cement, three parts standard sand. *Line B* shows the average strength developed by tests on these six samples of commercial cement after the addition of 5% of calcium aluminate. *Line C* shows the average results obtained from tests of the above six samples with a ten per cent. addition of calcium aluminate. *Line D* shows the results obtained by the addition of 10% aluminate to a natural cement made from selected perfectly burned rock. *Line E* shows average of 68 tests on seven brands Portland cement made at Structural Materials Testing Laboratory St. Louis. In every instance the cement after treatment was mixed one part cement to three parts standard sand and the briquettes were exposed one day in air and the balance of time in water.

due to the formation of a crust or skin of crystallized calcium carbonate which prevents the access of air and the further absorption of carbon dioxide and also the drying of the mortars by evaporation. In a closed chamber, for instance, the absorption of carbon dioxide by fresh mortar soon ceases. The absorption of carbon dioxide is also dependent on the presence of moisture.

It will be seen from this brief description of the hardening of lime mortars that the strength attained by them is variable and governed by local conditions.

For plastering purposes lime has been largely supplanted by what are commonly known as "patent plasters"; these have for their base calcined gypsum and harden by crystallization. Pure plaster of Paris is, however, not available for work of this kind, owing to the interference of the rapidity of set with the smooth working of the mortars made from it. This is overcome by the addition of lime and retarders which may be either organic or inorganic. Such plasters are commonly supplied to the building in the form of a dry powder already mixed with the necessary amount of sand and hair required, other materials acting in the form of a stretcher are frequently present. These plasters harden with considerable rapidity and allow of the early completion of the buildings and do away with the necessity of slaking the lime on the work. They are, however, subject to several objections. It is claimed by their critics that they are lacking in durability and also are more expensive to apply owing to their low sand-carrying qualities and to the fact that the lack of plasticity prevents the mechanics from covering the same area of wall in the course of a day's labor. These plasters are also criticized for their tendency to warp and crack, the set taking placing before the lath has had time to expand after being moistened by the mortar. Yet in spite of these objections, owing to the slow hardening of lime plasters and the time and space required in their preparation by the old methods, the patent plasters have made great inroads into the trade of the lime burners.

The addition of a small percentage of calcium aluminate to hydrated lime as demonstrated by use in actual building work will give to this material all the advantages of a hard wall plaster without its objections and restore to hydrated limes the plasticity and sand-carrying power of limes slaked in the old way.

The set being more gradual allows of ample opportunity for any expansion of the wood work due to the moisture, while the hardening, which is reasonably quick, will continue with years and the plaster after acquiring its initial set is not damaged by water, but on the contrary its strength is increased. This makes lime treated by aluminates available for stuccoing buildings and other out-door work and prevents damage to plaster through leaking of the roof or plumbing.

These advantages will enable the lime burner to meet on a direct competitive basis the manufacturer of patent plasters.

Considering next the use of aluminated limes for mortars in the laying of stone and brick walls, etc., the addition of calcium aluminate, with or without clay ingredients, to hydrated limes will enable the lime burner to compete with the cement manufacturer in supplying mortar for such construction where the work is not below water.

While the making of cement by the addition of aluminate has not yet reached a commercial scale, experimental work done indicates that equally good results will be attained as with plasters. If this proves to be the case and it is shown beyond possibility of doubt that the addition of a small percentage of aluminate to natural cements or to mechanical mixtures of hydrated lime and Puzzuolanic material will produce a cement having the strength of Portland cement at earlier periods combined with the unquestioned durability and stability of the natural and Puzzuolanic cements, the effect on the cement industry will be revolutionary.

As you all probably know the past fifteen or twenty years have witnessed a phenomenal growth in the use and production of cement and a decided change in the character of cements used. Prior to 1892, natural or what was commercially known as Rosendale cements were used even in the most important engineering construction. In 1893 there was used in the U. S., 8,211,181 barrels of natural cement and 2,966,558 barrels of Portland cement of which only 547,440 barrels were of American production. From 1893 to 1900 the use of Portland cement rapidly increased, the U. S. Geological Survey reports for the latter year showing a consumption of 8,383,519 barrels of natural cement and 10,803,430 barrels of Portland cement of which 2,321,416 barrels were imported. In 1907, 51,000,000,000 bar-

rels of Portland cement were used of which about 2,500,000 barrels were imported while the consumption of natural cement fell to 2,887,700 barrels compared with 9,868,000 barrels used in 1899. This lack of growth and falling off in the use of natural cement has been somewhat of a puzzle to thoughtful students of the subject. Popularly this decrease in the use of natural cement is accounted for by the impression or belief that natural cements are greatly inferior to Portland cements, both in strength and durability; this view, however, is only partly true and owes its origin to a comparison between tests made on Portland cements of to-day and those made on the natural cements produced by the crude methods that characterized the natural cement industry some years ago and which to some extent are still prevalent; yet these coarsely ground and carelessly combined and calcined cements proved equal to all strains imposed upon them by such structures as the first Brooklyn Bridge, the Croton Aqueduct, and other works of like magnitude.

It is perhaps well, for the sake of clearness, at this point to explain briefly the difference between Portland cement and natural cement in their character and action. As defined in the standard specifications, " Portland cement is a finely pulverized product resulting from the calcination to incipient fusion of an intimate mixture of properly proportioned argillaceous and calcareous materials and to which no addition greater than three per cent. has been made subsequent to calcination " while natural cement is defined as " a finely pulverized product resulting from the calcination of an argillaceous limestone at a temperature only sufficient to drive off carbonic acid gas." Both cements owe their cementitious properties to the same chemical components,—lime, silica, and alumina—and, as ordinarily made, differ chemically only in the ratio these components bear to each other. Broadly speaking, the Portland cements of commerce contain about two parts of lime to one of clay matter while in natural cement the ratio is about one to one, although the lime may approach that contained in Portland cement. It will be thus seen that the temperature of calcination is the most distinctive feature that differentiates Portland from natural cements.

Turning now to the difference noted in their use, the first point to be considered is the time of set, which, though part of the same phenomenon must not be confused with the ultimate

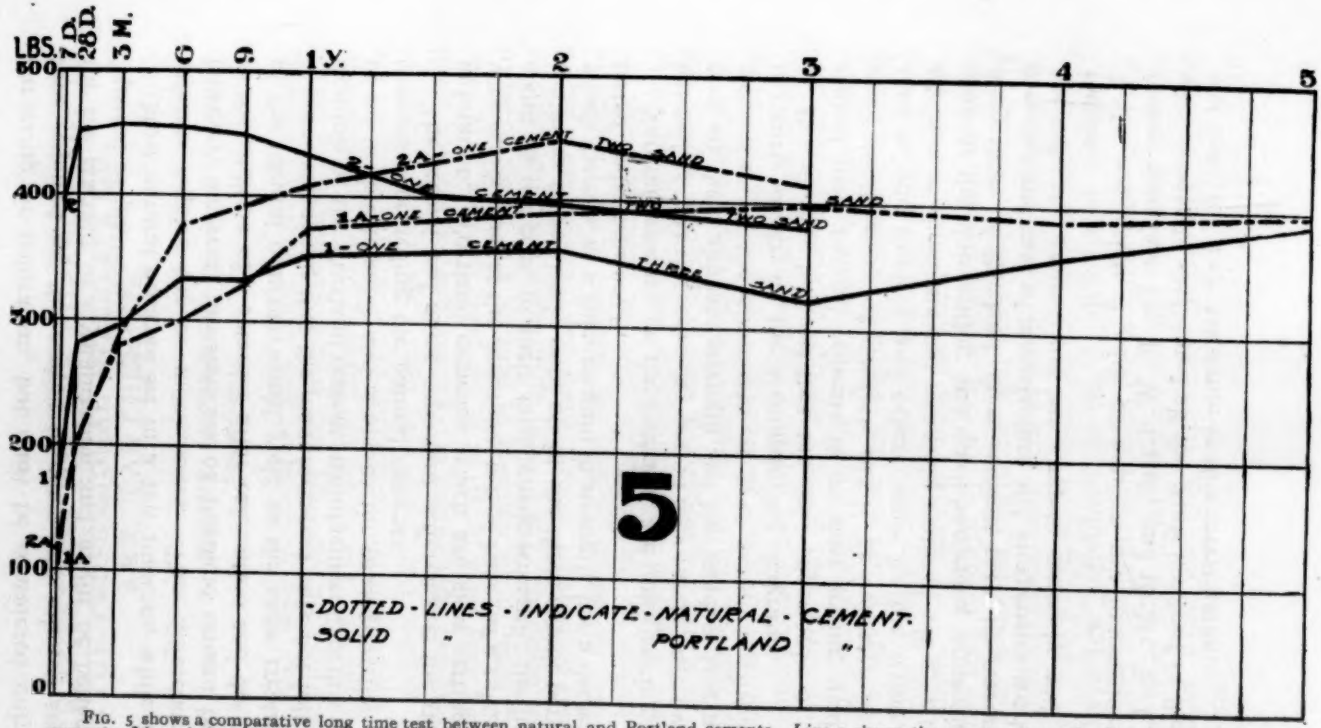


FIG. 5 shows a comparative long time test between natural and Portland cements. *Line* 1 shows the average strength of 14 brands of Portland cement. *Line* 1*A* shows the average strength developed by 9 samples of natural cement. The figures from which these curves are plotted were taken from the Report of the Operation of the Engineers Department of the District of Columbia for the year ending June 30, 1900 and the Portland cements used in these tests were made between 1885 and 1888 and were with possibly three exceptions, cements burned in the old fashioned set kilns. The average numbers six American cements and eight imported cements. *Line* 1 shows the average strength developed by a mixture of one part cement to three parts sand, one day in air, balance of time in water. *Line* 1*A* shows a mixture of one part cement to two parts sand, one day in air, balance of time in water. The data used in plotting lines 2 and 2*A* are taken from the Metropolitan Water and Sewage Board, Fifth Annual Report, January 1, 1906. *Line* 2 shows the average strength developed by eleven Portland cements mixed one part cement to two parts sand. These cements were probably all rotary kiln cements made between 1901 and 1903. *Line* 2*A* shows the strength developed by one brand of natural cement of which 182,480 bbls. were tested. This was mixed one part cement to two parts sand. All the briquettes were one day in air, balance of time in water. *Line* 2 shows the typical drop of Portland cement tested in tension referred to.

hardening or induration, but must be considered only as the time required for the cement to enter into solution sufficiently for the starting of crystallization and might be better termed "period of plasticity."

Most natural cements set in a few minutes, while Portland cements require one or more hours. This difference is not, however, inherent, the slow set of Portland cement being due to the addition of a retarder after calcination and the quick set of the natural cements would yield to the same treatment and it seems surprising that the manufacturers have not followed the example of the Portland cement manufacturers, as this quickness of set is objectionable and is one of the causes for the Portland cements superseding the natural cements.

The second and more important difference is the rapidity of induration. Portland cements, which are slow setting, harden very rapidly and at the seven-day period have, as a rule, acquired about 65 per cent. of their final tensile strength; the hardening continues more slowly until about the three-month period, after which there is, as a rule, no gain in strength, but a decrease when tested under tension.

Natural cements, on the contrary, are quick setting and slow hardening. At the seven-day period they rarely have over 25 per cent. of their ultimate strength and the increase is gradual and continuous to the six-month or year period. This condition is clearly shown by the accompanying diagrams.

It will thus be seen that the only superiority of Portland cement over natural cements is its slow setting qualities and rapid development of strength and if, as indicated by the tests read to you to-night and others made by the writer, a small addition of aluminate and retarding material will give to natural cements the slow-setting and quick-hardening properties resembling those of Portland, these cements may, by reason of their low cost and ease of manufacture and inexpensive works, regain not only the ground lost but compete seriously with Portland cement.

In conclusion, I wish to express my indebtedness to my former associate, Dr. E. W. Lazell, and to Mr. E. L. Conwell who personally performed all the work involved in the analyses and tests, for their assistance in this investigation.

SOME SUGGESTIONS FOR THE ADVANCEMENT OF THE PROFESSIONAL INTERESTS OF AMERICAN CHEMISTS.

BY

HENRY LEFFMANN,

Philadelphia.

THE large mass of literature now being produced annually on the subjects of sociology and economics indicates a period of serious unrest. The extent and intensity of the dissatisfaction with the methods of the distribution of the rewards for labor are probably greater than have ever been experienced. Changes more severe and more violent in organized government and social framework may have occurred in the past, but they have been limited in area, in the numbers of persons, and in the financial conditions involved. The present disturbance affects millions of people and millions of money, while the previous disturbances affected only thousands. Under the influence of the competitive system, backed by the results of inventive talent, scientific research, and a decline of true religious feeling, communities of even the most free and resourceful nations have been rapidly and ruthlessly divided into two classes,—the exploiters and the exploited, the bourgeoise and proletariat. In no case is this course of events more clearly and painfully evident than in this country. An immense area, rich in every material source of human comfort, lying undisturbed, except in a few places, until a century and a half ago, it has now an enormous population showing all the phases of misery and crime that attend overcrowding and underpayment. The abolition of a particular form of chattel-slavery has been followed by the extension of a system of wage-slavery that is no less degrading and disturbing. Natural resources, products of the land, such as water, timber, and minerals, have been everywhere taken under forms, or pretended forms, of law by a few individuals, to the deprivation of the many. The members of a liberal profession are probably much less liable to suffer from such misappropriation than the mass of those engaged in what are now technically known as "gainful occupations."

I have been asked by the management of the section work of the Institute to fill a space on the program for this meeting of the Chemistry Section, and it has occurred to me that it will be opportune to look about and see how the interests of practising chemists may be affected by the great economic evolution now taking place. Chemists can, indeed, scarcely be classed as a professional body in the strict sense of the term, for there is no definite organization governed by a code of ethics, and qualified to practise only after passing through a prescribed course of study. Even to-day, when so much is "regulated," any one may begin the practise of chemistry, and, so far as the *prima facie* status is concerned, rank with the best-trained worker.

Circumstances have saved chemists from the full incidence of the economic struggles that have borne down so many other wage-workers. One of these is the constantly increasing demand for chemists in connection with industrial development. It is easily within my memory when the employment of a chemist in connection with a manufacturing industry, a public service corporation, or a hospital was unknown and would have been regarded as a waste of money. I am quite familiar with the details of the original plans for establishing laboratories in connection with the Pennsylvania, Reading, and Baltimore & Ohio railroads. I made the first analyses for two of these corporations, consisting of examinations of the principal water stations along their lines, and I remember the efforts required to bring the general managers to see that systematic analysis in this and many other ways would be to the advantage of the corporations. The intense industrial struggle that began when the inventive talent of the country developed its force, compelled the resort to scientific methods and opened the field for the analyst so rapidly that for a time the demand exceeded the supply. The years of the fat kine are few, and the indications are that those of the lean kine have set in and are likely to be many. Several quite modern methods of operating are tending to place the chemist between the upper and nether millstone of the competitive system, and reduce him to the hopeless level of the specialized wage-worker. The colleges are doing a thriving business turning out bachelors and doctors of science and philosophy: the standarization of analytic processes is transforming laboratory work into a mere routine; the free supply of trained chemists is having its in-

variable effect on the compensation. Twice within a comparatively short period have I seen many righteous chemists forsaken. While business is booming, the industrial chemist profits somewhat, though not in proportion to his merit; but when the panic comes, he is thrown out without anything but a letter of recommendation.

Owing to the routine nature of many of the accepted analytic processes at the present day, much laboratory work requires but little ingenuity. The procedures are ordered with the formality of a cook-book or "Bob's Short Rules for Whist." For "one cupful of flour and a heaping teaspoonful of white sugar" read "50 c.c. of water and 5 c.c. of hydrochloric acid," and for "bake for twenty minutes in a quick oven" read "heat for half an hour at 100° with constant stirring," and we can see the relations between the cook and the chemist.

An editorial in the January number of *The Chemical Engineer* sets forth the conditions so vividly and authoritatively that I feel that I must quote freely from it. I deem it proper to say that the opinions expressed in this paper were formed before I saw this editorial, my attention having been called to it a few days ago by Mr. George C. Davis.

"All right-minded chemists who have had anything to do with general consulting work regret the tendency to commercialize analytical chemistry to the extent that the making of an analysis becomes as unprofessional a matter as the making of a chair or a cupboard. Many manufacturers are beginning to ask for bids on their analytical work, and are giving it as the result of these to the laboratory which will do it cheapest, without regard to the professional attainments of the man who is going to make the determinations. If this state of affairs continues, the profession of consulting analytic chemist will soon reach a point when our laboratories will be in charge of men with business heads rather than technical ability.

"The result of this tendency to commercialize analytical chemistry is beginning to make itself felt in a good many distressing ways. The following instance recently came to our attention. Two large foundries each employed a chemist. Both men were graduates of well-known technical schools with experience. A commercial laboratory was started in the neigh-

borhood. This laboratory came to each of the plants with a proposition to make their determinations at a flat rate of fifty cents each, and finally, failing to get the work at this price, they lowered it to a figure which amounted to twenty-three cents (ominous figure—L.) for a silicon determination. At this quotation both foundries were induced to let their chemists go.

"The commercial laboratory had for its head a young man of considerable business push, a college degree, and one or two years' experience in the laboratory of a large steel works. He knew that a Hungarian boy could be taught to make twenty or thirty determinations of silicon a day if some one else did the weighing. He knew that a boy of slightly more intelligence could be taught to run as many volumetric sulphur determinations. Figuring the boys' wages at $7 per week, he found it an easy proposition to make a fair profit on silicons at twenty-three cents each. . . .

"We have known business men who employed the highest priced physician in the town, their chauffeurs were engaged at a salary almost princely compared with that of the average chemist; when they had need to dodge the law, the attorney was a man whose fees ran into three figures; yet these same men would sit down and write a letter to every laboratory advertising in the engineering magazines, asking for quotations on analytical work, and invariably sent what they wished to have done to the man who made them the lowest price. . . .

"It is not only the chemist of poor experience and doubtful professional integrity who is taking his services to the auction room. . . .

"We know of one large laboratory headed by a man of the highest professional type, which formerly had its testing in the hands of experienced chemists and engineers, whose staff has now degenerated into a force of beaker washers and sample takers few of whom would be able to pass the entrance requirements of a first-class high school."

What remedies are available against this state of affairs? The materialistic conception of history—that is, history as the record of a struggle for existence under biologic principles, and not as the manifestation of supreme power working out a scheme of sin and redemption—shows us that but two methods are of

any effect. One is a complete absorption by the community of all competitive occupations; the other is combination of workers in any specialty to limit the number of qualified laborers and to compel by pains and penalties the observance of certain hours of labor and compensation, the latter called a wage-scale or a fee-bill according to the social position of the workers. One profession has from a remote period enforced to the utmost the second method. Lawyers maintain an absolute monopoly. No one can enter upon the practice of law in the courts of this Commonwealth, for instance, without undergoing examinations prescribed by the legal authorities. Even the entrance upon the study of law is stringently controlled, the required examination being more difficult than that exacted by the majority of professional schools. Moreover the professional privileges of members of the Bar are entirely in the keeping of that profession. For infringements upon its rules—that is, for being a "scab" workman—an attorney may be stricken from the list and thus wholly deprived of his means of livelihood. In the medical and dental professions infringements of the principles may be punished by exclusion or suspension from the societies, but the right to practise can be denied only by elaborate legal proceedings, to which the Bar as an organization lends no important aid, rather, indeed, interferes with it. Upon lawyers, as a class, the burden of professional life rests very lightly. They frame our laws and interpret them, and in the matter of fees and privileges they always know their own.

I do not think it will be safe for analysts to wait for the establishment of state control. It is necessary to turn to the other method. It is the object of this paper to advocate the plan that has of late been somewhat discussed elsewhere,—namely, to organize the practising analysts of the nation into a society for mutual protection. Such a society should carry on the same propaganda work that the medical, dental, and pharmaceutic societies are doing, especially secure legislation regulating the education of analysts and excluding all who do not conform to such requirements. Although the regulations concerning the three professions just mentioned are in this country, still unsatisfactory, yet much has been accomplished, and now no person can even enter upon the study of medicine or dentistry without complying with certain requirements, and the lines are

being drawn stricter every year. Members of these professions sometimes take offence when such regulations are declared to be analogous to the efforts of day laborers against "open shop," but the difference is often nominal. For my part, I consider it no condemnation of the efforts at restriction of the practice of the professions to classify it as the same in principle as that of the closed shop. I justify entirely the efforts of the wage-workers in their struggles. Without such control they would be reduced to minimum wages and be in desperate straits.

It behooves practising chemists, therefore, to make a national organization, the object of which shall be to promote their interests as against the efforts of the capitalistic class to degrade the professional standing and to reduce compensation to the minimum. It may be said that a national society is already in existence. The American Chemical Society does not and will not fulfil such a protective function. The controlling influences are and long have been those whose withers are wholly unwrung by the struggles of the independent worker. The society's attitude in this respect has been clearly emphasized by the recent proposition to admit "corporation" members. I do not know whether this plan has as yet succeeded, nor is that important. It will soon succeed. The bait offered is that such members will pay twenty-five dollars as against the ten dollars that individual members pay. Inasmuch as the financial condition of the society is rather Micawberish, the majority of members will feel that, whatever sentimental objection may exist against such admission, the society needs the money. In the same manner a local organization formed to collect, in social and intellectual relations, a certain class of persons, now finds itself in some financial stress, and proposes that associate members shall be permitted to vote and hold office, not because such members will be of advantage in the scientific work of the society, but again because it needs the money.

With the entrance of corporation members into active relations in the American Chemical Society, the power of the independent chemist will be still further put into the background. No resolutions disapproving of the practice of asking bids for analytic work could prevail at a meeting at which corporate interests were thus represented. It must not be forgotten that the corporate members will be regularly represented at the meet-

ings. Their object in accepting membership will be to have a representative to look after their interests and see that no sentimental action likely to diminish manufacturers' profits shall take place.

Holding that no present organization is sufficiently free from corporate control to be of use to the independent chemist, my advice is, as I have said, to form a new society. To give to such society a real ameliorating influence, it should be made up only of those who are directly interested. It should be based upon the principle applied in the formation of the British Society of Public Analysts. None but independent practising analysts should be eligible to membership. Teachers of chemistry in incorporated institutions, chemists wholly employed by corporations, chemists holding salaried positions under national, state, or municipal governments, should be excluded. All these persons are subject to a control, directly or indirectly, that would make them often lukewarm or even antagonistic to the interests of the independent workers. The professor of chemistry in a great university, recipient of a good salary and relying for any extra compensation upon consulting work brought by large corporations or public officers, feels no sympathy with the small fry who are doing odd jobs. I remember very well, in my own earlier experience as a general analyst, that a certain person then influential in Philadelphia scientific circles never recognized me as a chemist except when a subscription paper was being circulated. Then I was politely addressed as a fellow chemist and requested to send a check. Chemists connected with corporations under salary and those holding public office are not sufficient owners of themselves to be of much use in holding up a movement for independent standing in chemistry.

I hold, therefore, that the time has arrived for the independent analysts to form a society for mutual protection, this society to be national in scope with a thought of international affiliation. The name "American Institute of Chemistry" could be pre-empted now and would probably be satisfactory. As the burden of dues is now serious, the cost of membership should be as low as consistent with necessities. No attempt should be made to publish scientific proceedings or to expend money in social enjoyment, but the organization should devote its means to the uplifting of the professional character and to the prevention of the absolute commercialization of analysts.

Many will regard me as a calamity howler, and many others as offering a quack remedy. The recent effort within the American Chemical Society to form an Institute of Chemistry and the editorial in the *Chemical Engineer* from which I have quoted are evidences that something is rotten in the State of Chemistry, and that some counsel should be taken as to ways and means of eliminating the objectionable conditions.

TRANSPORTATION IN ALASKA.

Improved transportation facilities are admittedly among the most urgent needs of the mining industry in Alaska.

The field parties of the U. S. Geological Survey report that much progress was made during 1908 in the construction of roads and trails, but these can only supplement and can not supplant railways. The inadequacy of the river transportation lines in seasons of low water was strongly emphasized by the conditions that prevailed on the Yukon last summer.

The advancement of several railways, among which were the railways to the Matanuska coal fields and to the inland copper fields from both Valdez and Katalla, which had been actively pushed during 1907, was greatly retarded by the unfavorable financial conditions; but in gratifying contrast to the slow headway made by these enterprises was the rapid progress made by a railway being built up Copper River from Cordova. This line was completed to Childs Glacier in September. In connection with this road steamers are to be run from Abercrombie Rapids, so that during the coming year it will be possible to avoid the long overland journey from the coast to reach Chitina copper belt. As the railways in Alaska are of much public interest at present, the following table of mileage, compiled from the best available data, has been prepared for the Geological Survey's annual report on the mining industry in Alaska:

MILEAGE AND TERMINALS OF ALASKA RAILWAYS, DECEMBER 4, 1908.

	Miles.
Seward Peninsula:	
Seward Peninsula Ry., Nome to Shelton	80
Paystreak to Branch S. P. Ry.	6.5
Council City and Solomon River R. R., Council to Penelope Creek	32.5
Wild Goose Ry., Council to Ophir Creek	5
Fairbanks:	
Tanana Valley R. R., Fairbanks and Chena to Chatanika	46
Kenai Peninsula:	
Alaska Central R. R., Seward to near head of Turnagain Arm	53
Copper River:	
Copper River R. R., Cordova to Childs Glacier (Sept. 17)	47
(Probably 11 miles have been built since September 17. Same railroad at Katalla, where there has also been some work done by a rival company, has built between 3 and 4 miles. At Valdez a few miles of track of the Alaska Home Ry. were laid in 1907.)	
White Pass:	
White Pass and Yukon R. R., Skagway to White Pass	20.4
(Terminal at White Horse, Yukon Territory.)	
Yakutat Bay:	
Yakutat Southern Ry., Yaktutat to Situk River	9

Portions of the Council City and Solomon River and of the Alaska Central are out of repair and not in use.

NOVELTIES AS TO THE PREPARATION OF EXPLOSIVE CHARGES WITH A TRI-NITRO-TOLUOL BASE.

BY
M. R. ESCALES.*

Translated from the *Moniteur Scientifique* for August, 1908.

BY
W. J. WILLIAMS, F.I.C.

IT has been known for twenty years that tri-nitro-phenol (picric acid), $C_6H_2(NO_2)_3OH$ has played a considerable part in the technic of military explosives, and that it is used in enormous quantities in Germany as a charge for projectiles (Granatfüllung 88 and Sprengmunition 88), in France under the name of mélinite, in Italy called pertite, in England as lyddite, and in Japan as shimose powder. Tri-nitro-phenol, however, acts inconveniently as an acid and combines with metals or basic substances. These compounds are very susceptible to shock,[1] they explode easily, and consequently, acting as an opposite to the rest of the charge which remains almost wholly intact, they become an important factor. Besides this, the fine dust of picric acid is noxious to health.

In a paper, published in this journal in the first part of last year, J. Rudeloff has shown that for the above reasons, tri-nitro-toluol, $C_6H_2(NO_2)_3CH_3$, has become of greater and greater importance and has become a serious competitor of picric acid. In this communication, with the patents before us, we propose to describe certain novelties which have been discovered by Mr. Christian Emil Bichel, the eminent savant and technician who directs the Carbonite (Explosive) Co. In the first German

* Zeit. für das Gesamte Schiess- und Sprengstoffwesen, 1908, p. 21.

[1] According to Will, picric acid explodes under the blow of a weight of 2 kilogrammes, falling from any height between 35 and 95 cm., according to the conditions (*i.e.*, whether the explosive has been previously dried or not, whether it is pulverulent or compressed, unprotected or wrapped in tinfoil, or whether a piston is, or is not, interposed). On the other hand, the picrates explode with a low fall—5 cm. is enough for lead picrate, 7 cm. for iron or copper picrates.

patents (D.R.P. 177738 of Sept. 5, 1905) Mr. Bichel indicates a means of reuniting several small charges of a tri-nitro-toluol explosive into one large one. For military purposes it is of great importance that an explosive can take any form (shape) that may be desired. However, tri-nitro-toluol is easily fused on a water- or steam-bath (its fusion point is 81° C. to 81.5° C., or lower) and can be poured without danger into a shell or any hollow body. Moreover, as the density of tri-nitro-toluol is only 1.54, it is necessary to compress the flux under a relatively high pressure. Compression enables us to get a very dense explosive, which is desirable; for it is important to get the greatest possible weight of explosive into the limited space which occurs in a projectile, a mine, or a torpedo. But the compression of large charges presents many technical difficulties from different points of view, on one hand there is the danger that the charge in the zone nearest to the firing pin should reach too great a density (which would be the greater as the charge was longer); on the other hand, the size of the charge is limited by the danger to the neighborhood from its explosion. In order to prepare heavy charges of uniform density without any danger of explosion, it is desirable first to compress several small charges, and then to reunite them into a single charge. While reuniting these small charges there is no danger of an explosion if a nonexplosive agglomerant is used. However, Bichel has discovered that fused tri-nitro-toluol itself makes an excellent agglomerant, when it is poured, in the fused condition, on a charge of tri-nitro-toluol heated to a temperature near to the fusing point. If one or both of the surfaces of charges which it is desired to reunite are coated with melted tri-nitro-toluol, on cooling a joint is formed which cannot be broken even by very strong traction. In this way a charge of the shape and size desired can be produced from small charges of uniform density by reuniting them with an agglomerant of a density differing but little from that of the joined charges, which has a certain explosive power and which propagates the detonation from one portion to the other very thoroughly. The density of fused tri-nitro-toluol is about 1.54, that of compressed tri-nitro-toluol may reach 1.74, but is considered practically as 1.65. As this density differs but little from that of fused tri-nitro-toluol, by this method is avoided the contraction of the charge when cooling, the friction which results in loading

projectiles and the weak points which form the joints in such large charges as those in the points of torpedoes.

In the German patent, No. 181471, of November 4, 1905, Bichel indicates a novel method of protecting the explosive charges of tri-nitro-toluol (or other substances) from cracking and crumbling, by which means the charges become less sensitive to shock, and are more easily preserved. The system of wrapping them in cartridges, hitherto used, takes up too much space, and does not protect them from the shock to which the charge in the projectile is submitted at the moment of firing or when it reaches the target. Bichel covers the charge with a small bag of mixed, elastic tissue, either of animal or vegetable origin (silk, wool, or cotton) such as is usually made in the textile industry. The thickness of this knitted fabric can be varied at will. In its application, a band of this very elastic tissue is wrapped around the cartridge in such a way that it fits it well and can be well fastened. The ends may be folded over and pasted, or cut off. After the cartridge has been strengthened by its knitted envelope, it can be given its definite shape, and its resistance can be increased by painting with shellac or varnish or by dipping it in these materals. By using such an envelope, the resistance of the cartridge to the absorption of moisture is also increased.

However, tri-nitro-toluol alone is but little sensitive to shock, and moreover, cases may occur when it is desirable to increase this insensitiveness. According to the German patent, No. 181754, April 12, 1906, Bichel attains this result by adding naphthalene; to combine these two bodies, they should be fused together, or should be dissolved together, the solvent being afterwards removed by evaporation. They may also be mixed mechanically, afterwards applying pressure.

It is known that tri-nitro-toluol and naphthalene combine to form an "addition-product" in the proportion of one molecule of each; this compound can be mixed in all proportions with tri-nitro-toluol by fusion; and it is produced when tri-nitro-toluol and naphthalene are fused together in all proportions. The proportions in which these two bodies should be fused to attain the desired results are, however, limited on the one hand by the detonating power of the product, and on the other by the decrease of the explosive power. A convenient proportion, for example, is 5 per cent. of naphthalene to 95 per cent. of tri-nitro-toluol;

this compound shows a decrease in the percentage of the detonating power and the explosive power, as compared with those of tri-nitro-toluol, although the resistance to mechanical forces has been considerably increased. Thus, although tri-nitro-toluol can be exploded by the fall of a 20 kilogramme block through 5 cm., the above mixture can be exploded only by the fall of the same block through 15 c.m., the difference in the height of the fall is still more marked when a lighter block is used.

In the patents No. 185957 and No. 185958, July 17, 1906, Bichel treats of the way of increasing the density of fused tri-nitro-toluol (or other fusible explosives) so as to attain, when possible the density of compressed tri-nitro-toluol. When fused at atmospheric pressure, picric acid has a density of 1.62, while tri-nitro-toluol is 1.54. If these two substances are poured into a closed vessel, previously warmed, and so arranged that either a vacuum can be produced therein or a pressure of several atmospheres reached, the density of the explosive can be increased in proportion to the pressure exercised. In order to withdraw the air from the fused explosive, it is necessary, first, to exhaust the closed vessel; this increases the density from 1.54 to 1.58 if the atmospheric pressure is restored before solidification; but if compressed air is applied the density rises still higher; for two atmospheres it becomes 1.6, if a pressure of three or four atmospheres be exerted it becomes 1.62. If the pressure is increased above four atmospheres, no appreciable increase of density is observed except for very heavy charges. This process is particularly efficient if the bubbles of air occluded in the fused charge are removed by producing a vacuum, before applying compressed air or any other inert gas.

Bichel attains a still higher density and at the same time a finely crystallized condition, by quickly cooling the charge while applying compressed air. Cooling is effected by placing the vessel in cold water, or any other convenient means; but it is nevertheless better to use a special apparatus. The arrangement is as follows: the fused explosive is poured into an appropriate mold or into the projectile which should be placed in an hermetically closed envelope. This envelope is connected directly to the air-blast and is placed either actually in cold water or surrounded by a jacket in such a way that a current of cold water can be forced to circulate in the annular space between the envelope and the

jacket. The air-pipe enters the envelope which is hermetically closed on its upper surface. The envelope is fixed in threaded clamps. If desired, a battery of similar vessels can be used.

The use of tri-nitro-toluol is inconvenient in many cases; *e.g.*, if the projectile is not fitted with a (threaded) screwed base and the orifice at the ogival head is narrower than the interior space; it is impossible to introduce compressed tri-nitro-toluol without having blow-holes, and difficult with the simply fused material, while crystalline tri-nitro-toluol cannot be introduced without producing dust (powder). Bichel proposes to prepare tri-nitro-toluol for filling projectives in a plastic condition easy to form into a shape suitable for introduction and agglomeration under pressure.

According to the German patent, No. 193213, May 24, 1906, this result is attained by adding resins, either melted or in solution, to the tri-nitro-toluol, either pure or mixed with di-nitro-toluol; in this way, by the use of melted resins, for example, balsam of copaiba, crystalline tri-nitro-toluol can be transformed, with or without heating, into a plastic explosive, which detonates easily, and it can be easily worked in suitable mixers; or resins soluble in liquid hydrocarbons such as spirit of turpentine can be used. Liquid or solid resins, such as liquid storax or benzoin, can be mixed with so-called liquid di-nitro-toluol, and a mixture of this product with tri-nitro-toluol makes a plastic explosive. In any case, the plasticity can be increased, and made comparable to that of gelatine dynamite, by adding suitable quantities of collodion cotton. The resins and the di-nitro-toluol should be carefully purified and the collodion cotton can be added to the two substances, either before or after mixing them, provided the mixture is sufficiently heated when the additional collodion-cotton is introduced.

The resins and the di-nitro-toluol, are mixed with or without the collodion cotton, but at first without the tri-nitro-toluol for a long time while at the same time they are heated in an appropriate mixer, such as the Werner–Pfleiderer kneader, in such a way that they form a thick liquid; finally the tri-nitro-toluol is added; after which they are again mixed until they form a plastic mass easily molded. If the proportions are well chosen the product thus prepared should not adhere to the tools used for filling projectiles, cartridges, or torpedoes; it should be rammed down without any

air-bubbles and consequently has a high density. As the tri-nitro-toluol constitutes the essential part of the mixture, the proportions should be so chosen that the explosive force is not much lower than that of pure tri-nitro-toluol.

Here follow types of the mixture:

I.	a.	b.
Tri-nitro-toluol	87	87
Balsam of copaiba	13	12
Collodion cotton	—	1
	100	100

II.	a.	b.
Tri-nitro-toluol	85	85
Spirits of turpentine (larch)	15	14
Collodion cotton	—	1
	100	100

III.	a.	b.	c.	d.
Tri-nitro-toluol	85	85	85	85
Liquid storax	5	4.5	—	—
Liquid di-nitro-toluol	10	10	10	10
Collodion cotton	—	0.5	—	0.5
Benzoin (gum)	—	—	5	4.5
	100	100	100	100

COASTAL PLAIN INVESTIGATIONS.

STUDY OF UNDERGROUND WATERS.

An investigation of the Atlantic and Gulf Coastal Plain of the United States, with special reference to the ground water of the region, is being made by the United States Geological Survey in co-operation with the State surveys of the various States interested. This work is under the control of a supervisory board composed of members of the National Survey and of the State geologists. Prof. William Bullock Clark, State geologist of Maryland, is chairman of the board, and T. Wayland Vaughan has general charge, on behalf of the National Survey, of all the investigations. Professor Clark is in immediate charge of the work in the Coastal Plain district from Massachusetts to North Carolina, inclusive, and has been engaged during the past year with his assistants in directing the work in New Jersey, Delaware, Maryland, and Virginia.

WORK IN VIRGINIA AND NORTH CAROLINA.

The Coastal Plain studies in Virginia and North Carolina have for the first time afforded a knowledge of the sequence of geologic formations of this part of the area and will be valuable in determining the horizons at which underground water occurs. In connection with the State geological surveys of Virginia and North Carolina, it is planned to issue at an early date special bulletins on the geology and water resources of the Coastal Plain regions in these States, and these bulletins will be followed later by special detailed reports or monographs on the stratigraphy and paleontology. These reports will afford information regarding the middle Atlantic Coastal Plain of Virginia and North Carolina that has not heretofore been available.

FRANKLIN INSTITUTE

GRAVITATION.*

BY
CHARLES MORRIS.

Of the many problems with which science has had to contend in the recent centuries, that concerning the origin of the force of gravitation has proved by far the most difficult to solve. There is no other problem in which some progress towards a definite solution has not been made, but the question of gravitation remains practically in the position which it attained more than two centuries ago, when Sir Isaac Newton discovered its law of operation and offered a suggestion as to its probable cause. Many other hypotheses regarding it have been propounded since his day, but none of them have proved more satisfactory than that of Newton himself, and to-day the problem of gravitation remains in the precise state in which he left it, namely, that attraction as a force inherent in matter cannot exist, and that the gravitative force is probably in some way due to the action of an ethereal medium in contact with matter.

All the theorists, since Dr. Hooke in 1671, have employed this conception, and though none of them have succeeded in attaining the desired result, the impression is general among physicists that the basis of their arguments is correct. If, indeed, we deny the possibility of attraction, of the exercise of force by a body upon some distant body, of "action at a distance," as it is termed; we are obliged to accept the only alternative, that all exercise of force must come through actual contact. And as there is no visible substance in contact with matter to which

* In the "Journal" for February, 1906, the author published a paper on "The Problem of Gravitation," in which he made the phenomena of magnetic and electric attraction the basis of a hypothesis on this subject, drawing conclusions from these which seemed applicable to the gravitative force. He has since become convinced that his premises were incorrect and the result reached was erroneous. In the present hypothesis the phenomena of gravitation alone are considered.

the force of gravitation can be ascribed, we are obliged to suppose the existence of an invisible one. And this must be an universal one, if, as is believed, gravitation is an universal force. Such an agent would probably resemble in some or all respects the hypothetical luminiferous ether.

There seems no escape from this conclusion. We are aware that matter exists in a state of compression, and that its masses and particles alike manifest a tendency to move towards each other. If we deny that this is due to the agency of an inherent attractive force, we must look elsewhere for an agent capable of producing the effect. Such an agent, it would appear, must be some force-exerting substance in contact with matter, such, for instance, as the luminiferous ether, the assumed conveyer of the waves of light and other vibratory impulses. To this ether, or to some ether better adapted to the purpose, all theorists have turned in their attempts to solve the mystery of gravitation. Yet if the luminiferous ether fills all space, as is claimed, it is highly improbable that there is a second ether co-ordinate with it. At all events it is unphilosophical to seek for such a second ether until it has been shown that the ether of whose existence we have some evidence from the radiant phenomena of nature has been proven incapable of performing the necessary functions. In place of conceiving of a special ether as the agent in gravitation, it seems more logical to credit the ether which science so widely accepts with properties in addition to those usually ascribed to it, yet in accordance with its nature, and seek to discover if any such conceivable properties may afford an explanation of the phenomena of gravitation.

This has been attempted without success by many physicists. Yet, as there is no evidence that nature possesses any other agent capable of producing the observed results, the impression is somewhat general that gravitation must be a result of some activity in the agent to which is attributed the conveyance of the rays of light. Of late years there has been a tendency to ascribe the gravitative effect to some involved or intricate mode of ether motion. Yet the probability of this we may justly doubt. This is not nature's method of action. Its great results are produced by simple and direct means. It thus appears logical to assume that this, the greatest and most general of all its processes, the one upon which the very existence of the

material universe, as known to us, appears to depend, is the outcome of some such simple agency, not improbably the presence in the ether of some of the ordinary modes of motion which are visible or supposable in ordinary matter.

If we dismiss attraction as a force agency—as scientists very generally are disposed to do—we seem obliged to turn to the motion of some substance as the sole agent of force. At least the only agents suggested in all the years of scientific speculation on this subject have been attraction and motion. Each of these, acting from some substance, would be capable of exerting a compressive influence upon other substance, and we can conceive of no other agency competent to this effect. If attraction be dismissed motion alone remains, its force consisting in the momentum residing in some moving body.

Assuming then, in our study of gravitative phenomena, the necessary existence of an ether with properties adapting it to the purpose, the character of these properties comes next in question. The ether action can take only one of three forms; it must operate as a traction, a propulsion, or a pressure. Of these, traction—a drawing influence exerted upon matter by intermediate substance—has been avoided by theorists, none of them being able to suggest an effective mode of action of this kind. Propulsion—the force of impact—has been considered from various points of view, but ineffectively. Pressure has also been considered by theorists, with like unsatisfactory results. Yet from what we know of the phenomena in general, and of the progress of theory upon this subject, the latter seems the most probable and promising of the three methods.

Such is the status of the problem as it exists to-day, the foundation upon which any further study of the nature of gravitative force must be based. Newton's idea of the rarefaction of ether around masses of matter and a consequent pressure; Le Sage's conception of a second ether, consisting of swift moving corpuscles, acting through impact; Dr. Young's conception of the repulsion of ether by matter; and the many other hypotheses which have been propounded, have all been dismissed as inadequate, and all we have reached is the general proposition that gravitation is due to the action upon matter of some external energy, this presumably arising from some mode of motion in the luminiferous or other ether.

Before proceeding further two things must be considered: what modes of motion of a general or universal character are known to exist; and what do we know of the constitution and capabilities of the ether. In matter we are aware of only two general modes of motion, the direct motion of gaseous molecules, and the vibratory motion attributed to the molecules of solid material—the latter varying into curvilinear and circular motion. Ether, so far as hypothesis concerning it has gone, possesses but one mode of motion, the vibratory, the to-and-fro swing of its particles which is supposed to be the agency in light and other radiant manifestations. The assumption is that the ether particles are fixed in space and possess no direct motions, not darting about in the free and irregular manner attributed to gaseous molecules, but restricted to vibratory movements like those of the molecules of solid matter. Were the former the case, the motions which produce the phenomena of light would be dissipated and the transmission of light waves through space could not proceed. For this reason physicists hold that the ether must be similar to solid matter in its constitution or state of aggregation.

Of the other conditions of ether we know very little. It is regarded as a substance of extreme tenuity, and yet exceedingly rigid; as incompressible and yet highly elastic. Some maintain that it exists as a plenum, filling space to its full capacity, and yet possessed of a yielding capacity, so as to permit vibratory movements. Yet these suppositions seem to impose upon it irreconcilable conditions, and the fact that it admits of vibration renders it very probable that it possesses separate corpuscles, however minute, with space for them to move in, however contracted. That it is highly susceptible to movement we know from the freedom with which it responds to radiant impulses, and from this we may deduce the probability of its possessing movements native to itself, in addition to those impressed upon it by matter.

If ether be the seed stuff of matter, as is widely believed, it is reasonable to conclude that, as matter has absorbed only a minor portion of the substance of ether, so it has absorbed only a minor portion of its motions or activities. In such case it may possess active native motions and inherent energy of great intensity. Such would be necessary to make it the agent in the phenomena of gravitation.

If this be granted as probable, if ether does possess such a native mode of motion, of universal distribution, as contrasted with its partially distributed radiant motions, what is likely to be the character of this motion? The condition of the ether held to be requisite for the transmission of light, that is, the confined state of its particles, would appear to be preventive of any general movement through space, any power of direct transmission from place to place, and permit only some form of vibratory motion. And we may deduce from the fact that the molecules of each portion of matter vibrate at a fixed pitch, dependent upon their mass and condition, that the same is likely to be the case with the corpuscles of ether; since, in contrast to transitory vibrations, any native and persistent vibrations must be governed in rapidity by the constitution of the substance in which they exist.

Solid matter is capable of transmitting the vibrations of sound; but these, being at a pitch different from that normal to the molecules, are not absorbed by these. May not a similar condition exist in the ether? May not the radiant vibrations, at a great variety of pitch, impressed upon it by matter, similarly pass through it without absorption, while it has a persistent vibration of its own, at the pitch normal to its density? If the ether possesses any native motion at all, this is the form it must inevitably assume, supposing it to have the constitution usually attributed to it.

Let us assume the possibility of the existence of such an ether, filling all space not occupied by matter, capable of receiving vibratory impulses from matter and transmitting them intact to distant matter, and at the same time having vibratory motions native to itself and affecting its entire substance persistently. What deductions can we make from such a hypothesis? To be vibratory such an ether must be elastic. And if vibratory and elastic we cannot escape the conclusion that the corpuscles possess minute areas in which they move and to which they are confined. The density of such an ether would be due to its total quantity as compared with the area of space which it occupies in the universe. If its quantity be insufficient to fill this space absolutely there must be intervals, however minute, between its particles, and these would serve as areas of movement. The very rapid motion of the particles would enable them

to keep these areas practically occupied and also would give rise to a homogeneous density throughout, except where the presence of matter might affect the density.

If we may assume these premises to be correct, the ether would be incompressible only in this partial sense, it being everywhere compressed to the limit of its elastic powers of resistance. Returning now to the question of vibration, how shall we comprehend the to-and-fro swing of particles of either matter or ether, if the seeming force of attraction be disregarded? If attraction is absent, what is there to hold the particles in restraint and prevent them from moving straight onward and escaping to new localities? To convert such a power of onward movement into a vibration there must be a controlling agency of some kind present. If it be not a power within the particle, it must be a condition without it. Can we imagine any such condition? It may be that we have one in the elastic resistance of the surrounding ether. Taking the case of a single vibrating corpuscle, we can readily conceive of its swinging into a nest of resisting ether, as fixed in place as itself, compressing this in doing so, and being driven back by its elastic expansion, to be similarly checked and driven back at the opposite extremity of its swing. Forced back with accelerating rapidity to the centre of its field, it would be again checked and brought to rest by a similar agency in its other phase of vibratory movement, the process being indefinitely repeated.

What becomes of the lost motion of the particle when thus brought momentarily to rest? We are not prepared to accept the ordinary explanation of potential energy, a hypothesis widely used in science to explain phenomena of this kind, but which is purely metaphysical and absolutely without demonstration. A more logical explanation would be that the lost motion of the corpuscle is taken up by the resisting ether, which in its elastic reaction yields reverse motion of its own to the vibrating corpuscle.

We cannot well avoid this conclusion. If we discard the idea of an inherent force of attraction in matter, and decline to accept the questionable potential energy, the only conceivable other source of the loss and gain of motive energy by the corpuscle must be the action of some external motive energy, which in this case might well be that of the elastic resistance of sur-

rounding ether. Certainly it is not easy to imagine any other.

Leaving this phase of the subject and coming to the consideration of motion in its general aspects, the dictum of science is that all motion is normally persistent in force and direction. As no mass at rest can move of itself, so no mass in motion can lose or gain speed or change in direction of itself. Such changes can arise only from the action of external agents, and every change produced by these agents is compensated by an equal opposite change in themselves. Thus in the case of atmospheric molecules, which come into contact with each other thousands of millions of times every second, the motion of each molecule being incessantly diverted, the separate lines of motion, and the energy displayed in each, are never lost. They are simply transferred to other molecules, and pass unceasingly onward through space, being conveyed by myriads of molecules with the same effect as if they were conveyed by a single one.

This principle applies not only to free-moving particles, but to vibrating ones as well. We cannot imagine that the energy of the vibration is annihilated when the particle comes to rest at the extremity of its swing and new energy created when it returns. Nor can we logically imagine that the motion is temporarily changed into some condition of non-motion, as the hypothesis of potential energy demands. We therefore seem obliged to accept some such hypothesis of external influence as that suggested above, in which a compressible resisting substance takes up the lost motion, and by its elastic rebound imparts a reverse motion to the vibrating particle. In the case of vibrating ether corpuscles the surrounding ether may well be competent to perform this function. In the case of material molecules the surrounding ether may possibly perform the same function, the surrounding matter, presumably not in contact with them, being incapable of such an elastic function. In such a case the ether would act as the agent of a force analogous to that of gravitation so far as the particles of both matter and ether were concerned.

In fact, within the hypothesis here presented, if carried to its ultimate, may perhaps lie the solution of the whole problem of gravitation. This is the subject which we have next to consider. The motion of the vibrating ether corpuscle, when transferred to others, cannot vanish or lose any of its energy.

It must pass onward by interminable transfers from particle to particle. Thus we may consider space as being incessantly traversed by lines of motive energy, passing in every direction, unaccompanied by transfers of material, yet persistent in force and direction. In this transfer of energy matter and ether might both take part, though the ether, by virtue of its vastly greater space occupancy, would be the principal agent. It is adapted to this function by being highly susceptible to motive influences, and probably, like matter, normally in incessant motion.

The vibratory activity of the ether, thus formulated, would, as just stated, be far more than a local vibration. It would constitute a wave motion incessantly traversing space, analogous to the waves of light vibration, but differing from the latter in being longitudinal instead of transverse. Each vibrating corpuscle would cause a condensation of the ether into which it moved, this being followed by a rarefaction as it was elastically driven backwards, the energy embraced in its every swing being taken up by the resisting corpuscles, and in turn transferred by them to new corpuscles, thus passing indefinitely onward. There would thus arise a condensational-rarefactional wave like that of sound, differing from the latter principally in its agent and its vastly greater rapidity.

These lines of energy would not necessarily be confined to the ether, but might also traverse the particles of matter which they encountered in their course, their speed diminishing to correspond with the mass of these particles but their momentum remaining the same. And here the significant fact presents itself that wave motions of this type are of a kind adapting them to traverse matter in all its states, solid, liquid and gaseous alike, with equal facility, and ether also in all the states it is likely to assume. While transverse undulations, like those of light and radiant heat, are restricted to substance in the solid state of aggregation, longitudinal undulations have no such restriction, but are fitted to all known conditions of substance.

In a glance back at what has thus far been stated, it is apparent that this hypothesis adds nothing to the characteristics of ether assumed or conjectured to exist except the suggestion that, in addition to its radiant waves, it is in a state of incessant vibration, at a rate normal to its constitution, this yielding a

system of longitudinal waves which in their out-flow may be capable of traversing ether and matter alike. There is nothing revolutionary in this suggestion. If the ether possesses any native motion at all, as is highly probable, this is the form it is most likely to assume, a mode of motion distinct from that of its radiant waves and therefore not likely to interfere with the latter. Yet in the incessant and universal transfer of energy through space which this hypothesis suggests nature may possess an agency of remarkable power and efficiency. On ether itself this transfer of force would, with its compressive action, produce an effect resembling that of gravitation. On matter it may perhaps serve as the agent in all the phenomena of gravitation.

The material spheres, which, at vast distances asunder, are distributed like floating islands in the ocean of ether, are likely to be acted on by its energies, whatever form these may take. We perceive them affecting ether by their motions and producing in it a great variety of radiant waves. May not the ether in turn affect these spheres of matter by its normal motions and produce some equally marked effect upon them? Permeated as they are by the ether, which acts upon their every atom and every electron, we may justly suppose that there will be varied phenomena of action and reaction between these diverse forms of energy-containing substance. Some of these phenomena are apparent to us in the rays of light and heat, which arise from the energies of matter. It is very probable that there may be others, as yet unknown to us, arising from the energies of ether. It is with the latter that we are here concerned.

Returning to the form of universally transmitted energy which we have above attributed to the ether, it is in order to consider what effect it is likely to produce upon matter. If this energy were met by an equal resisting energy in matter, an exact balance of force would exist between the two types of substance. If unequal in energy, as is most probable, the stronger would exercise some degree of control over the weaker. If the ether energies were the stronger, the resulting conditions might well be those of gravitation. In such a case the great body of ether surrounding and permeating every sphere of matter, and acting upon it with the full vigor of its native energies, might produce a compressive effect upon the sphere as a whole and upon its every

part, and if the ether energy were sufficiently superior in force might bring about the spheral condensation which we perceive. We are not dealing here with any form of impact of moving ether, but with the force of transmitted vibrations of stationary ether, impinging incessantly upon the bodies of matter, and exerting a compressive influence upon them.

Let us consider any such body of matter acted upon on all sides and through all its substance by lines of force emanating from the boundless sea of ether, through the agency of the ether corpuscles in immediate contact with the material particles. This surrounding ether, if superior in energy to the matter acted upon, must exert a compressive effect, which we may here view in the separate cases of the three forms of matter. The resisting energy would be that of the molecular movements of matter, and if these be reduced by loss of heat the molecules might be pressed together so energetically as to cause them to enter the solid state. If, on the contrary, the heat energy of the molecules be increased the opposite effect would appear, they growing forcible enough to overcome in part the ether forces and break loose from their vibratory subjection into the freer mode of motion of the liquid. Still greater heat might enable the material to expand against the compressing force until it assumed the freedom of the gaseous state. Yet as the expansion of the gas would subject it to the compressive action of a much wider volume of ether, its molecules would still be held in partial captivity, and would need a much greater energy of motion to enable them to escape into cosmic space.

We are here brought back to our original premise, that if the compression of matter is not due to internal attraction, it must be due to external pressure. We have credited the ether with native energies under conditions that enable them to act incessantly upon matter, with the probability that they would exert the requisite compressive force. But there are other phenomena in gravitation than that of mere condensation, and no hypothesis can be regarded as tenable until it has been put to the test of explaining all the phenomena. To deal with these we must begin by taking the case of some single sphere, such as the sun, and seeing what probable effect such lines of ether energy would produce in it, beyond that of mere consolidation.

We know that the sun is a very porous body, containing far

wider areas of space than of matter, its particles being very minute as compared with the space surrounding them, and are satisfied that it is everywhere permeated by the rare ether, which comes into contact with its every particle and is in position to act upon every portion of its substance. As a result there seems likely to be a continual action and reaction between them, an unceasing conflict between their respective energies. If, now, as premised, the energies of the ether be superior in force, the particles of matter will be driven together until their aggregated energy enables them to prevent further condensation. Part of the ether energy would be employed in maintaining this state of compression, part of it would be taken up by the molecules and be transferred by them to the ether beyond, enabling it to act upon more interior molecules. Thus the ether would lose energy only to the extent that it exerted a moving or controlling force upon the particles with which it came in contact, its surplus energy passing forward through the intermediate matter to the ether beyond, to be there again employed. The compressing force must be continually exerted, since any diminution in it would be attended by an immediate expansion in the molecular groups, and any cessation by an explosive outflow of the molecules. Hence a continuous re-enforcement from external sources of the ether energy would be necessary and this re-enforcement would be constantly supplied.

The conclusion to which this line of argument leads is the following: The loss of energy by the ether through its action upon matter would by no means be total. A portion of it would be absorbed by the matter acted upon, while the remainder would be transmitted by aid of vibrations of the material particles to the ether beyond, much of the ether energy in this way traversing the solar mass. As a final result, the lines of force which penetrated the sun and emerged upon its opposite side would have lost much of their energy and be weakened to the full extent of the work they had performed, becoming much less effective than the fresh volumes of ether energy flowing in from space upon the opposite side of the sphere. As they have been engaged in producing and maintaining the condensation of the solar substance, they have decreased in energy accordingly.

If the probable existence of such a state of affairs be admit-

ted, it leads to conclusions of the highest importance. At every point on the sun's surface there would be an inflow of ether energy in full force, and an outflow of similar energy reduced in force to the extent of the internal work performed, the difference between these two sums of energy constituting the effective gravitative force at that point. Everywhere within the interior the same principle would apply, every internal molecule being differently affected upon its two sides, except those at the centre, where the inflowing volumes of gravitative force would become equalized. Everywhere else they would be impelled towards the centre. We would have here an effective mechanism, and one producing no heating effect upon matter, as in the case of the impacting corpuscles of the Le Sage hypothesis, since only that portion of the energy is absorbed which is necessary to maintain the gravitative compression.

The loss of ether energy here demanded would be analogous to the loss of heat energy by matter when it performs work, so that we may speak of the difference in condition between the inflowing and outflowing lines of ether force as practically a difference in temperature. But the point which it is especially desired to make here is that the decrease in energy of the outflowing ether must persist in the ether waves, or lines of vibration, as they flow swiftly outward through space, and may continue unchanged not only throughout the solar system but to indefinite distances beyond. As a result the sun would be surrounded by an ether atmosphere traversed in every direction by rays of vibratory energy of which those flowing inward toward the sun would be far more energetic than those flowing outward from it.

It is in this ether atmosphere that the earth and all the planets swim. In consequence, the inflowing ether energy would act upon them much more vigorously than the outflowing, the difference in propelling force being sufficient to give each of their molecules a slight set inward toward the sun, or, collectively, to impel the planetary mass as a whole in this direction, the agency affecting the planets being thus similar to that affecting the solar molecules. On the other hand, each planet would act similarly upon the ether and react upon the sun in the same manner, every cosmic body having an ether atmosphere of this kind effective upon other bodies in accordance with its mass and

distance. At every greater distance from the sun or planet, the volume of its weakened ether would occupy a greater spherical area, increasing, as could be geometrically demonstrated, in the proportion of the square of distance, the gravitative effect therefore weakening in exact conformity with the Newtonian law of gravitation. In this hypothesis, as will be perceived, we are not dealing with a shadowing of one sphere from ether impact by another, as in the Le Sage hypothesis, but with a permanent condition of the ether surrounding each sphere and affecting every mass of matter within its influence with a force dependent upon its distance.

The hypothesis here presented has a special significance, as it offers a solution of the most difficult problem in the phenomena of gravitation, one which no previous theory has even attempted to explain. This is that of the instaneous transmission of gravitative force, its apparent passage over enormous distances in infinitesimal periods of time. Under the present hypothesis this abstruse problem vanishes. There is no transmission of force to be dealt with. If the ether is permanently affected around every cosmic body, each mass at any distance from it must at every instant be subject to the gravitative force suitable to that distance, and in any change of distance feel a similar instantaneous effect as it entered a new region of the spheral atmosphere.

There is another important problem in the relations of ether and matter that must be here considered, that of the movement of the spheres through the ether without evident obstruction. The theory that the ether exists in the solid state adds to the difficulty of this problem. It is gravely attempted to be explained on the basis of the fact that a weight will pass through a jelly without leaving any trace of its passage. The ether is compared to a jelly of extreme thinness. But as no weight can sink through a jelly without obstruction and loss of speed, the parallel does not hold good, or would not unless the ether was of infinite thinness, a condition which we cannot predicate of any cosmic substance.

Under the present hypothesis, however, this problem assumes a different aspect. The ether is not passive in its action. It exerts a force on the moving earth which might be highly obstructive to movement but for the fact that it acts with equal

energy on every part of the surface, the lines of ether energy being as effective on the receding as on the advancing side of the earth in its orbital movement. Any increased pressure of the ether due to the earth's forward movement would be balanced by an equal increased reaction of the earth. And any decreased ether pressure on the receding side would be similarly balanced by a like decreased reaction of the earthly material. Thus it would appear that the variations in earth and ether action would be in exact balance and a moving sphere bear the same relation to the ether as a sphere at rest.

In conclusion it may be said that, under the terms of this hypothesis, the force of gravitation is only a portion, possibly a small portion, of the total energy of the ether, it being simply the difference in energy between the lines of ether energy that have been partly exhausted within a sphere and those of external ether. If we take the example of the molecules of the atmosphere, we would have the effect upon them of opposite lines of force: one series weakened by passing through the sphere, the other series in full strength; one pressing upward weakly, the other pressing downward strongly. The result would be the difference in energy between these two forces. The difference will increase the larger the sphere and the greater the internal work done. Thus, though the inflowing ether pressure on the sun would be the same as on the earth, the gravitative pressure would be much greater, on account of the greater enfeeblement of the ether that had traversed the sun. In open space the condensation of the ether is probably uniform, a fixed balance existing between the energies of compression and expansion. This balance may be disturbed by contact with matter, since there is reason to believe that the ether grows more dense in the interior of transparent bodies, where it meets with a diminished resistance. The ether which has penetrated a sphere would also probably be denser, from its fall in temperature or loss of energy and its consequent diminished power of resistance.

It may be desirable, in concluding this paper, to state briefly what results have been reached in preceding gravitation hypotheses. It is interesting to note that all of these are based on some action of an ether supposed to pervade space, and in nearly all cases they confine themselves to the energy effect of this substance on the spheres considered as wholes. Two only of

them are based upon a special ether, separate from the ordinarily accepted ether. Sir William Thomson (Lord Kelvin) suggests that the phenomena of gravitation might be explained by the action of an incompressible fluid filling all space, created constantly in each particle and flowing off into infinity, or created at infinite distances and flowing in all directions in upon each particle. This idea of incessant new creation is too remote from scientific conceptions to be for a moment considered. The other hypothesis is that of the ultramundane corpuscles of Le Sage, interesting from the fact that it alone among gravitation hypotheses gained wide acceptance, and still finds adherents.

The Le Sage corpuscles consist in a vast number of minute particles moving rapidly in all directions, impinging upon every mass of matter and condensing it by the force of their impact. Where two spheres are sufficiently near each other, each "shadows" the other, that is, screens the other from a certain number of the corpuscles. There are thus fewer blows on their opposed faces than on their more distant faces, and this excess of impacts on their distant sides acts to force them towards each other.

This hypothesis has the advantage of dealing with molecules and atoms as well as with spheres, its swift-flying corpuscles being supposed to penetrate the spheres to their inmost recesses. Its simplicity and conceivable adequacy, as compared with other hypotheses, has rendered it attractive, even to many scientists. Yet it has been rejected by the great body of physicists for several reasons. Its requirement of a second ether, pervading a universe supposed to be already fully occupied by an ether of different character, is exceedingly improbable. And Clerk-Maxwell has demonstrated that the energy exerted by these corpuscles would far surpass that needed for gravitative purposes and, converted into heat, would be sufficient to raise the spheres to a melting temperature in a brief period. As regards the problem of the instantaneous transmission of gravitative force, it does not deal with it at all.

These points are dwelt upon here from the fact that the present hypothesis, while radically different from that of Le Sage, is like it in dealing with an ether that penetrates the spheres and acts upon every molecule of matter, and also formulates a condition somewhat like that of the "shadowing" of

neighboring spheres by each other. It, however, deals with these subjects from a different point of view. Instead of presenting a flying corpuscle, striking the molecule with its full energy, and likely to yield far more force than is needed for gravitative purposes, it replaces impact by vibratory pressure in which only the energy needed is employed, all excess of energy being taken up by the molecules as vibration and passed onward to the ether beyond. Thus it does away with the necessity of a special ether, adapted to this function alone, and disposes of the difficulty of a surplus energy, while the "shadowing" action is replaced by a more effective mechanism. It farther is in accordance with the phenomenon of the instantaneous transmission over great distances of the gravitative effect. This is a crucial element in the problem. Instead of dealing with a simple action between sun and planet, it seeks to make this principle universal by showing that each sphere or mass of matter is surrounded by an atmosphere of weakened ether energy, decreasing in effect outwardly in strict accordance with the Newtonian law of gravitation. In this atmosphere all external spheres swim, so that their gravitation toward the acting body at each instant must exactly accord with their distance and vary in accordance with every change in distance, the time element being thus removed. There are other conditions, of a less stringent nature than this, demanded of all attempted explanations of gravitation, but these it is not necessary to name here, as none of them are violated by the present hypothesis.

[SUPPLEMENTARY NOTE.—Since reading the proofs of the above my attention has been called to an article by O. Keller, in Comptes Rendus, vol. 147, pages 853–856 (Nov. 9, 1908), on the Reaction of the Ether on Matter as a Cause of Universal Attraction in which the author shows that if the primary atoms (atomules) emit radiations, which like radiation, are capable of exerting pressure, then matter composed of atoms will be subjected to an attraction similar to that required by Newton's law of gravitation. In relation to this suggestion I would say that the conclusion reached is an obvious one, in view of the recent demonstration that the rays of light exert some degree of compressive force upon matter.]

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(Proceedings of the Stated Meeting held Wednesday, February 17th, 1909.)

HALL OF THE FRANKLIN INSTITUTE.

PHILADELPHIA, February 18th, 1909.

President Walton Clark in the Chair.

Present, 98 members and visitors. Additions to Membership since last report, 4.

The following communication from the Board of Managers was presented:

"At the stated meeting of the Board of Managers held on the 10th instant, it was

"*Resolved*, That the Board of Managers recommend that the Institute confer upon Dr. Wm. H. Wahl the title of 'Honorary Secretary.'"

On motion duly made and seconded, the recommendation was unanimously adopted.

The President announced the following Standing Committees for the current year:

Committee on Cabinet of Arts and Manufactures.

Cyrus Chambers, Jr., A. E. Outerbridge, Jr., Thomas Spencer,
Robert Job, Tinius Olsen, H. D. Stratton,
H. F. Colvin, E. S. Powers, Samuel Shoemaker,
William H. Thorne.

Committee on Cabinet of Models.

George S. Cullen, Francis Head, Werner Kaufmann,
Kern Dodge, Henry Howson, Strickland L. Kneass,
Spencer Fullerton, R. L. Humphrey, Coleman Sellers, Jr.,
Warner Walter.

Committee on Meetings.

James S. Rogers, J. Logan Fitts, Washington Jones,
James Christie, Prof. Lewis M. Haupt, J. Y. McConnell,
Kern Dodge, Coleman Sellers, Jr., Paul Thompson,
Dr. W. J. Williams.

Committee on Cabinet of Minerals and Geological Specimens.

Dr. Andrew A. Blair, Dr. F. A. Genth, Jr., Dr. Edwin J. Houston,
Prof. Amos P. Brown, Dr. E. Goldsmith, E. V. d'Invilliers,
Dr. Persifor Frazer, Dr. William H. Greene, Prof. Arthur J. Rowland,
Dr. William J. Williams.

Committee on Library.

Edwin S. Balch, Prof. Lewis M. Haupt, Louis E. Levy,
W. H. Gartley, Dr. H. F. Keller, Edward S. Miles,
Richard Gilpin, Dr. Henry Leffmann, C. E. Ronaldson,
Dr. George F. Stradling.

Committee on Meteorology.

Clarence A. Hall,	Dr. George A. Hoadley,	Prof. L. F. Rondinella,
Frank S. Hand,	W. N. Jennings,	Dr. Wilbur M. Stine,
Carl Hering,	Joseph T. Richards,	George S. Webster,
	Henry Pemberton, Jr.	

Prof. W. S. Franklin of Lehigh University, South Bethlehem, Pa., the speaker of the evening, was then introduced, and made an interesting address on the Gyroscope and Its Applications. The elementary dynamics of the Gyroscope and its various applications were considered. Special attention was given to its application in the Brennan Monorail Car.

The lecture was illustrated by apparatus and a model of the Brennan car in operation.

At the close of the meeting a vote of thanks was tendered the speaker.

Adjourned.

JAMES CHRISTIE,
Secretary.

LOUISIANA WORK IN WOOD PRESERVATION HAS GOOD RESULTS.

A CO-OPERATIVE agreement between the Forest Service and the North Louisiana Telephone Company for the investigation of economic methods for the preservation from decay of loblolly pine telephone poles has recently been carried out with gratifying results. The object of the government was to demonstrate that a creosote treatment could be applied successfully and at a low cost to loblolly pine poles. Such success was obtained that a company has been incorporated under the name of the Louisiana Creosoting Company, which will operate commercially the plant designed by the Forest Service.

The treating plant, which has been in operation since the latter part of October last, is of the "non-pressure," or "open tank" type. The installment of this style of plant costs much less than a plant of the "pressure" type, which is the ordinary type of plant for commercial purposes throughout the country. The "open-tank" system depends fundamentally upon the immersion of timber first in a hot bath of the preservative, followed by a rapid change to a cold bath. This method does away with the installment of high pressure and vacuum pumps and a treating cylinder of massive construction to withstand a high internal pressure, which are necessitated by a plant of the pressure type. It is usual, however, to install a treating cylinder of light construction where any great quantity of material is to be treated, since the cost of handling the material and loss of preservative through volatilization during the hot bath is in this way reduced to a minimum. Extensive experiments carried on by the Forest Service in recent years, have shown that the "open-tank" system is admirably adapted to the treatment of certain classes of timber, and especially so as regards loblolly pine.

The plant used in the experiment with the North Louisiana Telephone Company is equipped with a horizontal treating cylinder 50 feet long and 6 feet in diameter. It was designed by the Forest Service whose representative also supervised the construction and operated the plant for several months. During this period, 3,000 poles, 2,500 cross-arms, and 500 ties were treated, an amount sufficient to determine the most economical methods of treating these classes of material. The Forest Service therefore withdrew from the co-operation, and the plant is now being successfully operated by the owners.

GOLD AND SILVER MINING IN THE UNITED STATES IN 1908.

PRELIMINARY STATEMENT BY THE GEOLOGICAL SURVEY.

Gold.—According to a special press bulletin prepared by Waldemar Lindgren, of the United States Geological Survey, the gold-mining industry of the United States had a successful and prosperous year in 1908, in spite of many adverse conditions of trade and finance. Fundamentally, this prosperity is due to the fixed price and apparently limitless demand for the product. The immediate causes operating to increase the output were in part the removal of certain abnormal features tending to depress the production in 1907, such as the partial closing of the Homestake mine in the Black Hills of South Dakota and the labor difficulties in the Mother Lode counties of California. To some degree the increased production of gold is also indirectly due to the closing of many mines in the base-metal camps. A tendency toward increased production by small operators was noted as early as the last months of 1907 and continued through 1908. Large numbers of miners left the districts in which the output of lead, copper, and zinc was curtailed and began placer work or took up leases in gold-mining camps.

The Director of the Mint estimates the production of gold for 1908 from domestic sources at $96,313,256, against $90,435,700 in 1907. South Dakota, Alaska, California, and Colorado show large estimated increases, ranging from $2,000,000 to $3,600,000. The estimates for Utah indicate a decrease of about 1,200,000; for Nevada a decrease of 3,300,000. The production of Montana, Arizona, Idaho, Oregon, and other silver producing States has remained approximately stationary. The production from the Philippine Islands shows a gratifying increase, the estimate of the Mint being $306,708, against $78,700 in 1907. As part of the Philippine gold does not reach the United States mints the showing is probably even better than these figures would indicate. Most of the gold was recovered by quartz mining in Benguet and by dredging operations in Paracale.

The depression in the base-metal industries did not affect the gold production to any considerable degree, for the total base-metal ores contribute only 9 to 10 per cent. of the normal output of gold for the country. The gold from copper ores suffered little reduction, but the small amounts contributed from lead and zinc ores were much reduced.

Silver.—The silver-mining industry presents a far less satisfactory condition than that of gold, owing to the low prices for silver, lead, copper, and zinc. During the year the large smelters of Utah and Colorado were partly closed and partly operated on a reduced capacity. Important mines in Leadville, Aspen, Creede, and Park City, Colo., which were operating on low-grade ores, found it very difficult to make profits on ore of the same grades that yielded well in 1906 and 1907, and were therefore compelled to reduce their output or to close. Owing to temporary lack of demand from India the silver market declined almost continuously from about 56 cents per ounce in the early part of the year to about 48 cents in December, the average price being 53 cents. The year closed with New York prices at 50 cents. However, the purchases by India during past years have been large and have steadily increased, and there is no reason to expect a sudden falling off in this market. The extraordinarily heavy production of the Cobalt district in Canada, which for 1908 may approximate 17,000,000 ounces, undoubtedly contributed to the depression in the price of silver. A great reduction in the output of silver in the United States was clearly foreshadowed in the figures of the Geological Survey for the mine production of 1907, which amounted to only 52,500,104 fine ounces, whereas the refineries and the mints reported 56,514,700 fine ounces. The shortage in the mine output for the last months of 1907 was naturally reflected in the refinery returns for 1908, and was accentuated by still further reduction in the production of the mines. The Director of the Mint estimates the production of silver in 1908 from domestic sources at 51,798,053 fine ounces.

BOOK NOTICES

A SHORT PHARMACEUTICAL CHEMISTRY. Inorganic and Organic, by I. V. Stanley Stanislaus, M.S., Phar.D., Professor of Pharmacy and Organic Chemistry and Dean of the School of Pharmacy at the Medico-Chirurgical College of Philadelphia, and Charles H. Kimberly, B.S., (in Pharmacy) Ph.D., Professor of applied Chemistry in the School of Pharmaceutical Chemistry of the Medico-Chirurgical College of Philadelphia. Second Edition. Philada. D. Blakiston's Son & Company. Limp cloth, 5 x 7 inches, ix + 610 pages.

The text has been prepared from lectures and laboratory notes particularly intended for students of Pharmacy and the aim has been to present a systematic course in the subject with this object in view.

In revising the work for second edition, progress in the science during the period of eleven years that have elapsed since its first appearance has been borne in mind and the original matter fully revised.

Both Inorganic and Organic Chemistry are covered, condensed as far as possible by the omission of non-essentials, by reason of the limited time available to the study of Chemistry in a course in Pharmacy.

The book is conveniently arranged for quick reference and should well fulfil its intended object. L. E. P.

ANNUAIRE pour l'an 1909 publié par Le Bureau des Longitudes, avec des Notices Scientifique. 4 x 6 inches, paper cover; iv + 940 pages; price 1 fr. 50c. Paris, Gauthier-Villars, Quai des Grands-Augustins, 55.

Adhering to their usual custom of presenting each year papers on special subjects by authors of note, the publishers, this year, in addition to the standard data and tables relating to astronomy, physics, chemistry and engineering, include papers on Variable Stars by G. Bigourdan and on Motions and Deformations of the Earth's Crust by Ch. Lallemand. The work is a national standard and the data contained may be accepted as thoroughly reliable. L. E. P.

THE PRESENT STATUS OF MILITARY AERONAUTICS. By George O. Squier, Ph.D., Major Signal Corps, U. S. Army. iv + 71 pages, 6 x 9 inches, paper covers. 23 full page illustrations, diagrams, and tables. Reprinted from The Journal of the American Society of Mechanical Engineers.

Many of the important advances made in the act of transportation have received their first impetus and much of their subsequent development through the necessities and exacting requirements of military service. The presentation of the first paper reviewing the subject as a legitimate branch of engineering before the National Society of Mechanical Engineering by a military technologist is, therefore, an occasion of undoubted significance.

The most modern and successful derigible and aëroplane apparatus evolved both in this country and abroad are described in considerable detail along with the general considerations involved in both forms of apparatus. In an appendix are given the recent Government specifications for heavier-than-air flying machines and dirigible balloons in accordance with which were built the several forms of airship tested at Fort Meyer, Va., a short time ago. The appendix concludes with a sixteen-page bibliography and a list of aëronautical societies at home and abroad.

The student of aërodynamics seeking reliable information upon the latest advances in the art will find the paper true to its title. L. E. P.